New Scientist

WEEKLY 1 November 2025

THE SURPRISING WAYS PLAGUES SHAPED HUMAN HISTORY

WHY SOLAR IS GOING TO POWER THE WORLD SOONER THAN YOU THINK

HOW TO FIX THE WEB ACCORDING TO TIM BERNERS-LEE

NO SPACE NO TIME NO PARTICLES

A radical new vision of what quantum reality really looks like

By Vlatko Vedral

PLUS
HOW TO BE MORE ASSERTIVE /
LEGO ROBOT HAND /
CATS LOOKING COOL

No3567 £6.95
CAN$9.99

Aberdeen Investment Trusts

Invest in good company. Invest in your future.

Tax efficient investing

If you're keen to capture the potential offered by global investment markets, take a look at Aberdeen Investment Trusts. Managed by teams of experts, each of our trusts are designed to bring together the most compelling opportunities we can find to generate the investment growth or income you're looking for.

Tap into Aberdeen's specialist expertise across a wide range of different markets and investment sectors – both close to home and further afield. There's plenty of choice to target your specific investment goals, whichever stage of life you're at.

Please remember, the value of shares and the income from them can go down as well as up and you may get back less than the amount invested.

Tax treatment depends on the individual circumstances of each investor and may be subject to change in the future.

Eligible for Individual Savings Accounts (ISAs) and Self-Invested Personal Pensions (SIPPs).

Invest via leading platforms.

aberdeen

Find out more invtrusts.co.uk

Issued by abrdn Fund Managers Limited, registered in England and Wales (740118) at 280 Bishopsgate, London, EC2M 4AG. Authorised and regulated by the Financial Conduct Authority in the UK.

This week's issue

On the cover

30 No space, no time, no particles
A radical new vision of what quantum reality really looks like

Vol 268 No 3567
Cover image: Skizzomat

36 The surprising ways plagues changed human history

14 Why solar is going to power the world sooner than you think

40 How to fix the web according to Tim Berners-Lee

44 How to be more assertive
19 Lego robot hand
24 Cats looking cool

30 Features

"We have been misled into thinking particles are fundamental"

News

6 Fighting fibromyalgia
New studies shed light on this poorly understood condition

8 Liquid on Mars
Veins of water are a potential home for microbes

9 Defying quantum gravity
Gravity could produce quantum effects, even if it isn't fully quantum itself

Views

21 Comment
We need to face up to the hard climate choices ahead, says Susannah Fisher

22 The columnist
Chanda Prescod-Weinstein laments US science retreat

24 Aperture
Purr-fect pics of feline friends

26 Culture
New book ponders the origin of life and abstract thought

29 Letters
Could mental illness's roots lie in planning for the future?

JESPER SALOMONSEN/SOOPX/GETTY IMAGES

7 First light We may now know the reason why birds sing at dawn

Features

30 A new vision of reality
No space. No time. No particles. Could this be what quantum reality really looks like?

36 Ancient plagues
How a surge in contagious diseases in Europe 5000 years ago helped shape humanity

40 How to fix the web
Tim Berners-Lee shares how to save the World Wide Web

The back pages

44 Dear David
How to stand up for yourself better

45 Puzzles
Try our crossword, quick quiz and logic puzzle

46 *Almost* the last word
Which animals can recognise individual people?

48 Feedback
Minecraft fails to block the AI revolution

48 Twisteddoodles for New Scientist
Picturing the lighter side of life

We know wealth
is having enough to invest in yourself
If you're thinking of taking a leap, our wealth advisers can help plan your next move. Financial and other eligibility criteria apply.*
HSBC Wealth
Savings | Investments | Retirement
HSBC UK | Opening up a world of opportunity

***HSBC UK current account customers with online or mobile banking only. Minimum £100,000 in Investments or Savings is required to qualify for the Financial Advice service. Other eligibility criteria & fees apply.**

Issued by HSBC UK Bank plc, 1 Centenary Square, Birmingham, B1 1HQ, United Kingdom. ©HSBC Group 2025. All Rights Reserved. AC68508

Your data, your control

Only by taking data back into our own hands can we fix the web

IT IS a familiar pattern. A new website or app arrives that is so good you just have to try it. It's free, so why not? You and millions of others quickly become hooked, using it every day. But then it starts to change.

Some of your favourite features can now only be used for a fee. Ads start to interfere with your user experience. It's still the same thing, only now it's a bit worse, a bit more corporate, a bit less fun.

What has happened, using a term coined by author Cory Doctorow, is "enshittification" (see page 25). Users are no longer the priority; shareholders are.

The internet is filled with examples of this, so much so that it now defines the story of the web itself. Most of us rely on just a handful of apps and websites owned by tech giants, many of which aren't quite as good as they once were.

The result, according to Tim Berners-Lee, is that his creation, the World Wide Web, is "as likely to induce anxiety as joy."

Damning words. But as he explains on page 40, it doesn't have to be this way. The problem is that we don't control our own data. We give it up to tech companies. Leaving is hard; if you do, you lose that data.

> "Most of us rely on just a handful of apps, many of which aren't quite as good as they once were"

His solution is something called a data pod. Whenever you generate personal data, it goes into the pod. You can then share this whenever you want, with whomever you want, but you can just as quickly revoke sharing permissions and take your data elsewhere.

Data pods would certainly make it easier to ditch tech companies that go down the enshittification route. Rather than being locked in, you could leave and simply bring all your data with you. A stick in the hands of users, to balance the carrot of shareholder profit.

But how to introduce such a thing? Berners-Lee thinks that a critical mass of early adopters will eventually be able to demand it, but tech companies are unlikely to voluntarily give up some of their control. That leaves the state. With governments increasingly looking at ways to reduce the power of the big tech firms, forcing them to hand back control of our data would be a good start. ▮

PUBLISHING & COMMERCIAL

Commercial and events director Adrian Newton

Display advertising
Tel +44 (0)203 615 6456
Email displayads@newscientist.com
Sales director Claudia Nicoletti
Account manager Mila Gantcheva
Agency partner Tilly Pollock

Recruitment advertising
Tel +44 (0)203 615 6458 **Email** nssales@newscientist.com
Recruitment sales director Viren Vadgama

New Scientist Events
Tel +44 (0)203 615 6554 **Email** live@newscientist.com
Sales director Jacqui McCarron
Sales manager Maureen Ignacio
Head of event production Martin Davies
Head of product management (Events, Courses & Commercial Projects) Henry Gomm
Marketing manager Emiley Partington
Events and projects executive Georgia Hill
Events team assistant Olivia Abbott
Events co-ordinator Stephanie Best

New Scientist Discovery Tours
Email tours@newscientist.com
Director Kevin Currie
Senior product manager Lara Paxton
Product manager Pip Orchard

Marketing & Data
Head of campaign marketing James Nicholson
Subscription acquisitions manager Molly Hayde
Campaign marketing coordinator Charlotte Weeks
Head of customer experience Emma Robinson
Engagement marketing manager Kelly Spillane
Senior marketing executive Sarah Fabian
Head of CRM & audience data Rachael Dunderdale
Senior email marketing executive Natalie Valls
Email marketing executive Ffion Evans
Digital marketing designer Katarina Pollu
Junior analyst Hamied Fahim

Technology & Product
Head of product Remy Becher
Head of product design Irmak Sunal Lutkin
Director of engineering Michael Ilett
Principal engineers Phil John, Tom McQuillan
Senior engineers Maria Garrido, Amardeep Sian, Matt Watson
QA Engineer Kaveri Daitkar
Lead digital designer and developer Dan Pudsey

Partnerships
Consultant editor Justin Mullins

NewScientist

Chief executive Roland Agambar
Chief operating officer Jonas Hermans
Chief financial officer Depak Patel
Chair Nina Wright
Executive assistant Lorraine Lodge

Finance & operations
Head of finance Charlotte Lion
Head of finance (maternity cover) Anna Labuz
Management Accountant Ilir Morina
HR business partner Tinka Bleijenberg

CONTACT US

newscientist.com/contact

General & media enquiries
UK 9 Derry Street, London, W8 5HY
Australia 58 Gipps Street, Collingwood, Victoria 3066
US 600 Fifth Avenue, 7th Floor, NY 10020

UK Newsstand
Marketforce UK Ltd
Email mfcommunications@futurenet.com

Syndication
Tribune Content Agency **Tel** +44 (0)20 7588 7588
Email tca-articlesales@tribpub.com

Subscriptions
newscientist.com/subscription
One year print subscription (51 issues) UK £270
Tel +44 (0)330 333 9470
Email subscriptions@newscientist.com
Post New Scientist, Rockwood House, Perrymount Road, Haywards Heath, West Sussex RH16 3DH

© 2025 New Scientist Ltd, England. New Scientist is published weekly by New Scientist Ltd. ISSN 0262 4079. New Scientist (Online) ISSN 2059 5387. Registered at the Post Office as a newspaper and printed in England by Warners Midlands Plc

recycle
When you have finished with this magazine please recycle it.

EDITORIAL

Editor Catherine de Lange
Executive editor Timothy Revell
Managing editor Penny Sarchet
Creative director Craig Mackie

News
News editor Jacob Aron
Assistant news editors Alexandra Thompson, Sam Wong
Reporters (UK) Madeleine Cuff, Michael Le Page, Matthew Sparkes, Alex Wilkins, Carissa Wong (Aus) Alice Klein, James Woodford

Digital
Head of audience Matt Hambly
Podcast editor Rowan Hooper
Head of editorial video David Stock
Social media manager Isabel Baldwin
Video producer Obomate Briggs

Features
Head of features Claudia Canavan
Deputy head of features Joshua Howgego
Editors Abigail Beall, Leah Crane, Kate Douglas, Alison George, Olivia Goldhill, Jacklin Kwan, Thomas Lewton
Feature writer Graham Lawton

Culture and Community
Comment and culture editor Alison Flood
Senior culture editor Liz Else

Magazine
Magazine editor Eleanor Parsons
Assistant magazine editor Michael Dalton

Subeditors
Chief subeditor Kelsey Hayes
Bethan Ackerley, Tom Campbell, Tom Leslie

Design
Art editor Ryan Wills
Joe Hetzel, Phoebe Watts

Picture desk
Picture editor Tim Boddy
Assistant picture editor Jenny Quiggin

Production
Production manager Joanne Keogh

New Scientist US
US editor Chelsea Whyte
Subeditor Alexis Wnuk
Deputy audience editor Gerardo Bandera
Reporters Karmela Padavic-Callaghan, Grace Wade

A tough watch to advertise.

The **C63 Sealander Extreme GMT** is a GADA watch. But harder. Born to beat the elements and thrive in high-impact environments, its marine-grade steel case prevents water ingress down to 150-metres. Built with an anti-shock movement holder, it also sports a sandblasted, ceramic 24-hour bezel. And a dial designed for maximum day or night-time legibility. Unsurprisingly, the only component that isn't over-engineered is its price.

Do your research.

Christopher Ward

christopherward.com

News

Clues in the clouds
Colours of microbes in clouds could help us spot alien life p7

Signs of promise
'Weaponised' CAR T-cells eradicate solid tumours in mice p8

Better batteries
Tweaked lithium-ion battery can be pierced by a nail p10

Civet coffee's secret
Why the coffee beans from civet poo taste so delicious p17

Disease defence
Gene editing protects pigs from classical swine fever p18

Zoology

Joining crabs on their commute

A young boy walks beside some red crabs on Christmas Island, an Australian territory, as they embark upon their annual migration. More than 100 million red crabs travel across the island annually, going from the rainforest to the sea to mate and spawn. Roads are often closed to facilitate the migration, which began this year in October. A major spawning event is expected to take place in mid-November.

ASSOCIATED PRESS/ALAMY

Health

Solving the mystery of fibromyalgia

Fibromyalgia, which causes chronic pain, is poorly understood, but two studies have shed new light on its causes, explains **Michael Marshall**

WE ARE starting to unpick the genetics of fibromyalgia, a condition that causes chronic pain all over the body. The results of two studies – with millions of participants between them – support the idea that dysfunction in the central nervous system is a major factor. However, previous research suggests alternative mechanisms, such as autoimmunity, are involved, hinting at the condition's multi-causal complexity.

Fibromyalgia is thought to affect 2 to 3 per cent of people. Its causes are unclear, which makes it difficult to treat, but a leading idea is that people with fibromyalgia have developed changes in the way their central nervous system processes pain messages, possibly due to an infection or changes to the gut microbiome.

To understand the role of genetics, two sets of researchers have carried out genome-wide association studies to identify genetic variants more common in people with fibromyalgia. Both studies focused only on variations to single letters in the genome, rather than other variants, such as large-scale deletions, which can have a more dramatic effect.

The first study – led by Michael Wainberg at Mount Sinai Hospital in Toronto, Canada – pulled together cohorts from multiple countries, including the US, the UK and Finland. The team amassed a total of 54,629 people with fibromyalgia, most of whom were of European ancestry, and 2,509,126 people without the condition. From this, the team identified 26 variants in the genome associated with a higher fibromyalgia risk (medRxiv, doi.org/qbrh).

Existing treatments for fibromyalgia, including exercise, have mixed success

Joel Gelernter at Yale School of Medicine led the second study, which used datasets from the US and UK. Altogether, Gelernter and his colleagues looked at 85,139 people with fibromyalgia and 1,642,433 people without it, who had a mix of European, Latin American and African ancestries. They found 10 variants associated with fibromyalgia in the European group, one in the African group and 12 that were cross-ancestry (medRxiv, doi.org/qbrj).

"These are first steps, but they open the possibility of understanding the roots of fibromyalgia"

Wainberg and Gelernter declined to be interviewed because their studies haven't yet been peer-reviewed.

"Both studies, in terms of sample size, are really great," says Cindy Boer at Erasmus Medical Center in Rotterdam, the Netherlands.

In Wainberg and his team's study, the strongest association was with a variant in a gene called *huntingtin*, which can cause the neurodegenerative condition Huntington's disease. However, this condition is caused by a repeated genetic sequence within *huntingtin*, leading to the production of a defective protein. In contrast, the variant linked to fibromyalgia is a single-letter change in a different part of the gene.

But this doesn't mean that this mutation alone causes fibromyalgia, says Boer. There are probably thousands of variants at work, she says. Identifying them would require even larger studies.

Despite these shortcomings, the variants implicated in Wainberg and his team's study were all in genes that have roles in neurons, suggesting many key mechanisms of fibromyalgia occur in the brain. Likewise, Gelernter and his team's study identified variants that have previously been linked to pain and brain-related issues, such as post-traumatic stress disorder.

These results solidify an existing hypothesis about fibromyalgia: "there's something going on in brain tissues", says Boer. Follow-up work on the implicated variants could identify key cell types, brain regions and biochemical pathways, which could be targeted for treatments, but these are probably many years away, Boer warns. Existing interventions focus on exercise, antidepressants and talking therapies, with mixed success.

NATALIE BEHRING/AP/ALAMY

Another explanation?

However, David Andersson at King's College London and his team have previously found evidence that fibromyalgia is an autoimmune condition. In 2021, they showed that when antibodies from people with fibromyalgia were injected into mice, they developed painful hypersensitivity and muscle weakness.

In September this year, the researchers showed that such mice had abnormal responses to sensations, with nerves that normally respond to light touch starting to respond to cold as well. This mirrors how people with fibromyalgia often feel pain in response to stimuli that other people don't find painful, such as slightly cold temperatures.

But Boer stresses the latest studies don't invalidate that. The researchers set a high bar for statistical significance, so while we can be confident about the variants they identified, they will have missed many more, she says. Also, Gelernter and his team identified some variants associated with autoimmune responses.

Studies like these are "first steps", says Boer, but they open the possibility of understanding the roots of fibromyalgia. "What are the pathways?" she asks. "And is there something in there that we can target?" ▮

Ornithology

We may finally know the reason why birds break into song at dawn

James Woodford

THE dawn chorus of birdsong has inspired poets and nature lovers for thousands of years, but the reason why birds start the day this way is an enduring mystery.

Now, a series of experiments in zebra finches (*Taeniopygia guttata*) suggests that while darkness inhibits singing, birds build up a stronger motivation to sing in the night that causes them to burst into song at dawn.

Satoshi Kojima at the Korea Brain Research Institute in Daegu, South Korea, and his colleagues studied laboratory-raised zebra finches in carefully controlled lighting conditions to manipulate the timing of light and dark cycles.

The team first pushed back the time at which the finches were exposed to sudden bright light to 3 hours later than the actual dawn. The birds were awake but stayed silent in the artificial darkness, and when the lights eventually did come on, the birds sang more intensely than usual.

When the lights came on 3 hours earlier than true dawn, the birds still broke into a chorus, but without the same intensity as when they were forced to wait.

In other words, says Kojima, the longer the time lag between when the birds wake up and the onset of light, the more intense the chorus.

"The birds are already awake in the dark before the lights come on," he says. "But their spontaneous singing is suppressed by the darkness. This suppression elevates their motivation to sing, leading to a high rate of singing as a rebound immediately after the lights are turned on."

The researchers then trained birds to press a lever to gain 10 seconds of artificial light. When the simulated daylight was delayed by 3 hours, the birds pressed the lever frequently, but they rarely did so when the artificial daylight was 3 hours earlier.

Next, they administered the drug luzindole, which blocks the effects of melatonin, a hormone released in the night-time that helps to regulate wakefulness cycles in many animals. Birds that were given this drug 5 hours before the normal lights-on time woke up more quickly and began singing earlier than those given a saline injection instead.

Kojima and his colleagues also analysed the birds' songs to see how these changed over the course of the day. They found there were rapid shifts in the structure of the songs in the first hour after dawn, compared with the second (bioRxiv, doi.org/qbrc).

"Due to the absence of singing during the night, the vocal motor system and song acoustic structure may slightly deteriorate, and the dawn chorus serves to quickly restore or optimise them," says Kojima.

While this study only looked at one species, similar drivers may apply to other bird species, he says.

But Diego Gil at the National Museum of Natural Sciences in Madrid, Spain, urges caution. There are "myriad differences between species in how, when and what birds sing in the dawn chorus", he says. "This explains why 11 different hypotheses have been proposed to understand the phenomenon." ▮

Zebra finches are one of many bird species that sing when the sun comes up

SAGAR SIMKHADA/ALAMY

Space

Cloud microbes' colours could help us spot alien life

THE colours of microbes that live in clouds high in the sky have been measured for the first time, giving scientists clues that could help us find life on other planets.

A diverse range of microorganisms have been found living high in Earth's atmosphere at concentrations of up to 100,000 microbes per cubic metre, and they are known to play a role in cloud formation.

These organisms produce pigments to protect themselves from the strong ultraviolet light at extreme altitudes.

If similar airborne life forms exist in the atmosphere of other planets, we could therefore detect them from afar by analysing the wavelengths, or spectra, of light that those planets reflect, says Ligia Coelho at Cornell University in New York state.

To learn more about the colours of airborne microbes on Earth, Coelho cultured microbes collected by Brent Christner at the University of Florida and his colleagues. Christner's team used a helium balloon to capture the microbes on sticky rods between 3 and 38 kilometres above Earth's surface.

Coelho's team then measured the reflectance spectra of the coloured compounds produced by the microbes. They generated a range of yellow, orange and pink colours, created by carotenoid pigments such as beta-carotene, which is also found in carrots.

Finally, the team modelled how these spectra would vary on worlds with different environmental conditions – such as wetter or drier planets (arXiv, doi.org/qbrb).

"If similar airborne life forms exist on other planets, we could detect them from afar"

"Our planetary simulations show that if a planet's clouds had high concentrations of these microorganisms, their spectra would potentially change in a detectable way," says Coelho.

However, even with more advanced instruments, the concentrations of airborne microbes would have to be very high for us to detect them from such great distances. ▮

JW

Health

‘Weaponised’ CAR T-cell therapy shows promise against solid tumours

Michael Le Page

IMMUNE cells that have been genetically engineered to kill cancerous cells, known as CAR T-cells, have transformed the treatment of blood cancers but proved largely ineffective against solid tumours. Now, “weaponised” CAR T-cells have eradicated large solid prostate tumours in mice, raising hopes this approach will work in people.

“The tumours were gone, completely gone,” says Jun Ishihara at Imperial College London. It is the first time such results have been achieved in an animal study, he says.

Our immune system kills off many cancers before they become a problem. Mutant proteins on the surface of cancer cells are recognised as foreign, and immune cells known as T-cells are sent to eliminate them. T-cells identify cancerous cells using receptor proteins on their surface that bind to the mutant proteins.

Not all cancers provoke an immune response, but biologists realised in the 1980s that it is possible to genetically modify T-cells to target them. This is done by adding a gene for an artificial receptor protein known as a chimeric antigen receptor – hence the name CAR T.

CAR T-cells have effectively cured blood cancers in some people, but have failed against the vast majority of cancers that form solid tumours. This is because the cells in solid tumours don’t all have the same mutant protein on their surface. Solid tumours are also good at thwarting immune attacks by producing signals that say “don’t attack me”.

So, researchers have tried weaponising CAR T-cells by making them produce potent immune-stimulating proteins, such as interleukin 12. But these therapies have made the immune response so strong that it damages many healthy tissues.

Ishihara and his colleagues have found a way to localise interleukin 12 to tumours. They first fused

“The modified CAR T-cells completely eradicated large prostate tumours in four out of five mice”

the interleukin with part of a protein that binds to collagen. The collagen-binding protein normally seeks out collagen exposed in wounded blood vessels to aid healing, but tumours are similar to wounds in having exposed collagen, says Ishihara.

Next, they modified CAR T-cells so the fused protein is produced after these T-cells bind to a mutant protein found on some prostate cancers. Once released, the fused protein should bind to collagen within tumours and remain localised, with the interleukin 12 part effectively shouting, “Attack!”

In tests, the treatment completely eradicated large prostate tumours in four out of five mice. When the mice were later reinjected with cancerous cells, they didn’t develop tumours, showing that the CAR T-cells had provoked an effective immune response (*Nature Biomedical Engineering*, doi.org/qbh2).

Ishihara’s team hopes to start clinical trials in people within two years.

Steven Albelda at the University of Pennsylvania in Philadelphia says other groups are also working on ways to localise interleukin 12 to tumours, and some have had promising results. ▮

Solar system

Liquid veins on Mars are potential home for microbes

THE Red Planet may have a network of liquid water flowing through the frozen ground. All buried permafrost, on Earth and beyond, is expected to host narrow veins of liquid, and new calculations show on Mars, these could be big enough to support life.

“For Mars we always live on the edge of maybe habitable, maybe not, so I set out to do this research thinking maybe I can close this loop and say that it’s very unlikely to have enough water and have it be arranged so that it’s habitable for microbes,” says Hanna Sizemore at the Planetary Science Institute in Arizona. “I proved myself wrong.”

She and her colleagues used measurements of Martian soil composition to calculate the size of the channels that could form and how much of the icy soil could actually be liquid water. It is tricky to keep water liquid on Mars because temperatures can get as low as -150°C (-240°F). However, while pure water freezes at 0°C, the abundant salts on Mars can dissolve in the water there and lower its freezing point significantly.

The researchers found it was “surprisingly easy” to get soil with more than 5 per cent liquid, running in channels at least 5 micrometres in diameter – the requirements they set for the veins to be considered habitable (*Icarus*, doi.org/qbhx).

Based on soil measurements from NASA’s Phoenix spacecraft, which landed on Mars in 2008, these networks of channels could be abundant at latitudes higher than 50 degrees. If there is life on Mars, the liquid veins would be the easiest place to look for it, says Sizemore.

“We have to be careful, though, about using the limits in which terrestrial life can grow and metabolise, as they do not necessarily represent the limits in which any life, anywhere, could function,” says Bruce Jakosky at the University of Colorado Boulder. ▮

Leah Crane

NASA/JPL-CALTECH/UNIVERSITY OF ARIZONA/TEXAS A&M UNIVERSITY

Thin layers of water frost on the Martian surface captured by NASA’s Phoenix lander

Quantum physics

Defying quantum gravity

A new calculation has found that gravity could produce quantum entanglement, even if it isn't fully quantum itself, finds **Karmela Padavic-Callaghan**

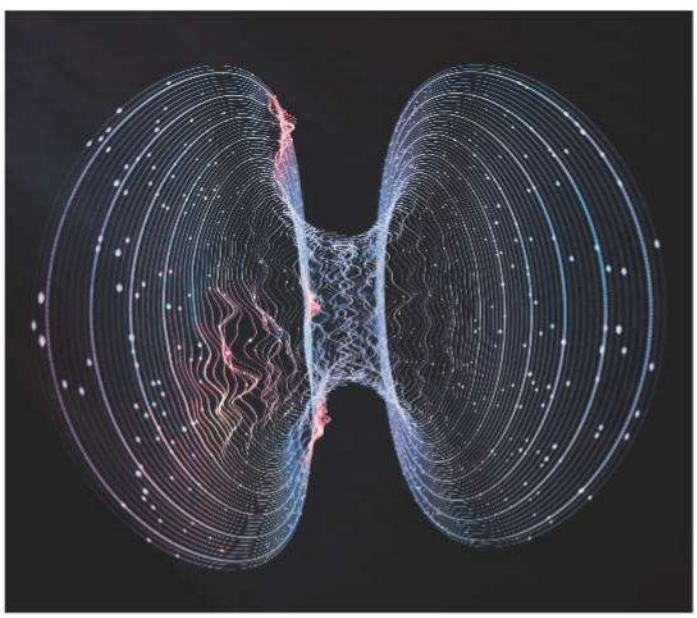
THE decades-long quest to understand how quantum physics and gravity mix may have just become even more complicated. It has long been thought that gravity may need to be carried by quantum particles called gravitons, in order to fit with a grand unified theory of the universe. But a new calculation suggests that quantum phenomena could arise from gravitational fields that aren't fully quantum themselves.

Many physicists think that at the level of its smallest building blocks, our world is quantum. This means objects are made from quantum particles, and the forces that act on those objects – such as the strong and weak forces, the electromagnetic force and gravity – are carried by quantum particles. We know which particles carry the first three of those forces, but gravity, a fundamental force that stems from the very shape of our space-time, has so far resisted such quantisation.

To remedy this, researchers have been searching for gravitons, and experiments are being built to look for signs that gravity creates the inextricable and fundamentally quantum link between particles called entanglement. But Richard Howl and Joseph Aziz at Royal Holloway, University of London, have now found that the issue may not be so simple.

They began their mathematical analysis with a gravitational field – a map of gravitational force that any object that has mass would feel at any point in space. Crucially, the field they analysed wasn't quantum in nature. It couldn't assume a quantum superposition, in which it could simultaneously have more than one quantum property and we couldn't tell which is real.

Then, they plugged this non-quantum field into the full mathematical machinery of quantum field theory. When they used this framework to calculate how two objects with mass would interact, they found that the gravitational field could sometimes give rise to an effect that made them quantum entangled (*Nature*, doi.org/g97xb6).



KOTO_FEJA/GETTY IMAGES

There are many theories as to how quantum physics and gravity may mix

Howl says this is because the two objects can exchange "virtual matter" that emerges from the gravitational field. This isn't an oddity in the physics of fields – it is similar to an effect seen with electromagnetic fields, where objects exchange virtual particles of light, or virtual photons. These have the same effect that a real photon would, but they can't be measured. But there is one big difference: the electromagnetic field is known to be quantum. Because Aziz and Howl formulated their gravitational field as non-quantum, and there are no gravitons in the picture, what does their finding then say about the quantumness of gravity?

"If we were to say whether gravity is quantum or classical, then I guess we would be saying that question doesn't have a binary answer," says Howl. In other words, even without being explicitly quantum, the gravitational field may not exclude all quantum phenomena.

"The question of whether gravity is quantum or classical may not have a binary answer"

The team's calculations add nuance to how we ought to interpret experiments aiming to diagnose gravity's quantum nature, says Markus Aspelmeyer at the University of Vienna in Austria. "It says, look, if you do your experiment and you see entanglement when you let two particles interact gravitationally, there is actually a parameter regime within which there can be another explanation that is actually not based on any quantum gravity assumptions. That is a very, very nice insight."

Keeping the door open

This may be interpreted as a new way to think about gravity, but it could also be seen as a separate effect from gravity altogether. In this scenario, the gravitational field would merely influence the strength of the interaction but not directly cause it, says Jonathan Oppenheim at University College London.

Similarly, Sougato Bose at University College London says the exchange of virtual matter is qualitatively different from the exchange of virtual gravitons, which is the conventional view of how quantum gravity would work. In his view, the research has revealed a new way for massive bodies to interact, distinct from gravity.

The new effect would be most prominent for objects with masses much larger than those in experiments currently being constructed to fully probe quantum gravity. Bose, who has initiated some of those experiments, says there is no chance that this new effect will show up as a spurious signal there.

Additionally, Aspelmeyer says that for extremely small masses – for instance, microdiamonds that weigh only a quadrillionth of a kilogram – an explanation for entanglement through classical gravity still isn't possible. Because of this, the new work doesn't negate the need for a quantum theory of gravity, he says. "This door is not closed." ▮

To read more about quantum theory, turn to page 30

Health

Eye implant and high-tech glasses help restore lost vision

Chris Simms

MOORFIELDS EYE HOSPITAL

A study participant, fitted with a retinal implant, tests her sight

PEOPLE with severe vision loss have been able to read again, thanks to a tiny wireless chip implanted in one of their eyes and a pair of high-tech glasses.

Age-related macular degeneration (AMD) is a common condition that affects the middle part of someone's vision, often worsening over time. Its exact cause is unknown, but it occurs when light-sensitive photoreceptor cells and neurons in the centre of the retina become damaged, making it hard to recognise faces or read. Approved treatments can only slow its progression.

People with an advanced stage of AMD known as geographic atrophy usually retain some photoreceptor cells that allow for peripheral vision and enough retinal neurons to pass visual information to the brain.

Taking advantage of this, Daniel Palanker at Stanford University in California and his colleagues have developed a device called PRIMA. It involves a small camera mounted on a pair of glasses that captures images, then projects them via infrared light to a 2-by-2-millimetre solar-powered, wireless chip implanted in the back of the eye.

The chip then converts the image information into an electrical signal that retinal neurons can pass to the brain. Infrared light is used because we can't see in this wavelength, so the process doesn't interfere with any existing vision. "This means patients can use both prosthetic and peripheral vision simultaneously," says Palanker.

To put it to the test, the researchers recruited 32 people aged 60 or older who had geographic atrophy. Their vision in at least one eye was worse than 20/320, which means they could only see at 20 feet (6 metres) what a person with 20/20 vision could see at 320 feet (97.5 metres).

The researchers first implanted the chip in the eyes of one of the participants, then, four to five weeks later, the volunteers began to use the glasses in their daily lives. The glasses allowed them to magnify what they were seeing by up to 12 times and to adjust the brightness and contrast. After a year, 27 of the participants could read again, as well as perceive shapes and patterns. They could also see an additional five lines, on average, on a standard eye test chart, compared with what they could discern at the start of the study. Some could even read with the equivalent of 20/42 vision (*The New England Journal of Medicine*, doi.org/g97d24).

"When you watch them starting to read letters and then words, it's an increasing joy on both sides. I recollect one patient telling me: 'I thought my eyes were dead and now they are alive again'," says team member José-Alain Sahel at the University of Pittsburgh School of Medicine in Pennsylvania.

By giving participants the ability to perceive shapes and patterns, PRIMA represents the first eye prosthesis to restore functional sight in people with the condition. About two-thirds of the volunteers experienced short-term side effects as a result of the implant, but this didn't prevent vision improvements.

"This is an exciting and significant study," says Francesca Cordeiro at Imperial College London. "It gives hope for providing vision in patients for whom this was more science fiction than reality."

The boosted vision the participants experienced is in black and white. "Our next goal is to add the software that will help resolve grey scales and enhance them for face recognition," says Palanker. ▮

Technology

Safer battery can be pierced without catching fire

Matthew Sparkes

CHANGING just one of the materials used in lithium-ion batteries could prevent the uncontrollable fires that erupt if they are pierced or bent.

Lithium-ion batteries used in smartphones and laptops contain a graphite electrode, a metal oxide electrode and an electrolyte of lithium salt dissolved in a solvent. The liquid electrolyte allows ions to flow in one direction to charge the battery and in the other direction to release energy and power devices. But if this design is punctured in such a way that it creates a short circuit, all the chemical energy stored inside is released rapidly, which can cause a fire or explosion.

Now, Yue Sun at the Chinese University of Hong Kong and her colleagues have created a safe design that can be built exactly like existing batteries, thanks to a change in the electrolyte material (*Nature Energy*, doi.org/qbhk).

Fires occur when negatively charged ions, called anions, break their bonds with lithium in the battery. As the bonds break, they release more heat and keep the destructive cycle going in a process called thermal runaway.

To get around this, the researchers created a second solvent called lithium bis(fluorosulfonyl)imide that bonds with the lithium from the existing solvent only at higher temperatures, when thermal runaway is beginning. Unlike the usual solvent, anion bonds can't exist in this new solvent. When pierced with a nail, the temperature inside the battery rose by only 3.5°C, while conventional batteries can heat up by more than 500°C.

"It's a big leap in battery safety," says Gary Leeke at the University of Birmingham, UK. He says the findings could be incorporated into the next generation of batteries and then be mass-produced in three to five years. ▮

Physics

Testing relativity in the quantum realm

Rotating ultracold atoms in an "optical Ferris wheel" could help us reveal the limits of relativity

Karmela Padavic-Callaghan

TINY "Ferris wheels" made from light and extremely cold particles could allow researchers to test a facet of Albert Einstein's theory of relativity on unprecedentedly small scales.

Theories of special and general relativity, which Einstein formulated in the early 1900s, reshaped our understanding of time by revealing that moving clocks can tick more slowly than those that stay still. If you move sufficiently quickly or if you accelerate enough, the time you measure will become dilated; the same can happen if you find yourself moving in circles.

These phenomena have been observed for relatively large objects, but Vassilis Lembessis at King Saud University in Saudi Arabia and his colleagues have now devised a way to test them on very small scales.

To study rotations and time for the smallest objects we can control – atoms and molecules – they turned to the ultracold realm, just a few millionths of a degree above absolute zero. Here, quantum properties, as well as the motion of atoms and molecules, can be manipulated extremely precisely with laser beams and electromagnetic fields.

In fact, in 2007, Lembessis and several other colleagues developed a method for tuning laser beams so they keep atoms confined to and rotating within the shape of a cylinder. They called it an "optical Ferris wheel", and Lembessis says his team's new calculations show it could be used to observe relativistic time dilation as measured by the ultracold particles.

Their calculations show nitrogen molecules would be a good candidate for testing rotational time dilation in the quantum world. Considering the motion of electrons within them as ticks of an internal clock, the researchers could detect a shift in ticking frequency as small as one part in 10 quadrillion (*Physical Review A*, doi.org/qbhh).

"It is when we get a surprise that we gain a deeper understanding of the universe"

At the same time, Lembessis says experiments with optical Ferris wheels have so far been relatively rare. Because of this, the new proposal opens the door for testing relativity in an unexplored setting where new or unexpected effects may arise. For instance, the quantum nature of ultracold particles may call into question the "clock hypothesis", which dictates just how much a clock's acceleration changes its ticks.

"It is important to check and confirm our understanding of physical phenomena in nature. It is when we get a surprise, something unexpected, that we need to revise our understanding and gain a deeper understanding of the universe. This work suggests an alternative way to check relativistic systems with some clear advantages compared to mechanical setups," says Patrik Öhberg at Heriot-Watt University in the UK.

For instance, while relativistic effects like time dilation usually call for very fast motion, using the optical Ferris wheel would make them accessible without needing impractically high speeds, says Aidan Arnold at the University of Strathclyde in the UK. ▮

Health

Wegovy helps the heart even with minimal weight loss

THE weight-loss drug Wegovy curbs the risk of heart attacks even among people who don't lose much weight on the drug, a study has shown.

Earlier results from the same trial, called SELECT, suggested Wegovy – a weight loss drug that contains the GLP-1 medicine semaglutide – may have this effect, but it wasn't clear if the heart health benefits were just due to weight loss.

"The take-home message is that the benefit of these drugs for your heart and arteries is not dependent on your weight loss," says John Deanfield at University College London.

The SELECT trial compared semaglutide against a placebo on the cardiovascular risks of 17,604 people, aged 45 and older, who were overweight or obese. None had diabetes, but they all had some form of heart disease. In November 2023, Deanfield and his colleagues reported semaglutide reduced the risk of a heart attack, stroke or other major cardiac event by 20 per cent.

SHELBY KNOWLES/BLOOMBERG VIA GETTY IMAGES

Weight-loss drugs, like Wegovy, may have numerous health benefits

They have now scrutinised their data across different body mass index (BMI) and weight-loss categories, and found that people with a starting BMI of 27 – considered mild obesity in some cases – had similar improvements in their heart disease risks after taking semaglutide as those with the highest BMIs, which reached 44 (*The Lancet*, doi.org/qbhj).

The team also realised the amount of weight lost had little bearing on the cardiovascular benefits.

But having a smaller waist at the start of the study was linked to a lower risk of cardiovascular problems. Over the course of a couple of years on semaglutide, each 5-centimetre reduction in waist circumference was associated with about a 9 per cent lower risk of cardiovascular events.

The team calculated the waistline drop accounted for roughly a third of the drug's heart-protective benefit; the rest of its effects were less clear. ▮

Christa Lesté-Lasserre

Advertorial paid for by vodafone business SAMSUNG

How an AI phone can make your business more productive

Smartphones have already transformed the ways business leaders work in 21st century Britain – and new AI phones are rewriting the rules again.

There's a huge number of functions built into the Samsung Galaxy S25, powered by Vodafone Business' reliable award-winning network[1], doing everything from recording and transcribing meetings to a morning bulletin with alerts for your schedule.

Business-focused functions help to turn your phone into an AI-powered office on the go including Writing Assist[2] which can help you transform your own drafts into truly effective pieces of communication, suggesting tweaks to grammar, syntax, spelling and more. Galaxy AI helps you keep on top of the important things throughout the day. And the Now Bar[3] on your lock screen lets business leaders instantly access active apps such as Maps, Samsung Wallet and Samsung Notes.

Instant transcripts

Meetings and customer calls are a staple of small business life, and Galaxy AI lets business leaders stay on top of these. Secure phone call recordings of a customer call can be transcribed into text, then summarised for easy review with the Transcript Assist[3] feature.

And with Interpreter[4] a meeting with an international supplier can be transcribed instantly with live translation into 20 languages.

Additionally, Note Assist[3] turns that transcript into useful notes and bullet points (and corrects spelling), with a key word search on Galaxy S25 making it easy to find important points later.

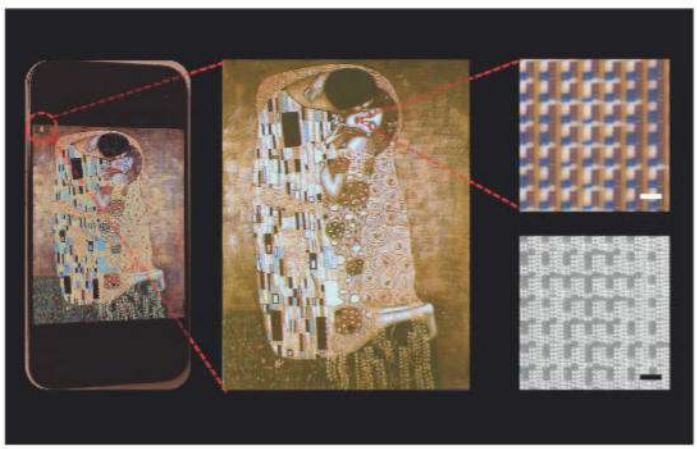
Scan here to find out more about how Vodafone Business and the Samsung Galaxy S25 can help your business

1. Verification of claim: vodafone.co.uk/network. 2. Samsung account login is required. Requires a network connection. Must meet length requirements to activate feature. Service availability may vary by language. Accuracy of results is not guaranteed. 3. Samsung account login is required. Requires network connection. 4. Samsung account login is required. Certain languages may require language pack download. Service availability may vary by language. Accuracy of results is not guaranteed. Available in 20 languages from launch.

Technology

A leap forward for e-paper displays

Chris Stokel-Walker



KINGSTON FRAMEWORKS, KUNLI XIONG ET AL. (2025)

Left to right: *The Kiss* on an iPhone, the same image on the e-paper, and two views of the e-paper's subpixels

A NEW kind of colour e-paper can present bright, high-resolution, full-colour images and video while using minimal energy, pointing to a possible future for display devices.

While traditional LED screens emit red, green and blue light to produce images, e-paper screens use tiny molecules. Until recently, these devices were limited to black and white, but colour screens are now available. Still, they struggle to refresh fast enough to display video.

To address this, Kunli Xiong at the University of Uppsala, Sweden, and his colleagues have developed e-paper with pixels made from tungsten oxide nanodiscs (*Nature*, doi.org/qbdk). Each pixel is around 560 nanometres across, giving the paper a resolution of 25,000 pixels per inch (PPI). By contrast, smartphones typically have a PPI in the hundreds.

The tungsten-oxide nanodiscs are made with slightly different sizes and spacings so each reflects a particular band of light. By placing them together, it is possible to present a range of colours, and the brightness can be varied by a brief electrical pulse that places an ion inside the disc. Once a colour is set, the ions stay put and the colour holds without continuous power.

The researchers created an e-paper display measuring just 1.9 millimetres by 1.4 millimetres, which is around 1/4000th the area of a normal smartphone display, and used it to display a 4300-by-700 pixel crop of Gustav Klimt's *The Kiss* – an extremely high resolution for such a small device. It can also refresh roughly every 40 milliseconds, which is fast enough to display video.

Another benefit of the new e-paper is its incredibly low energy use, says Xiong. The display uses around 1.7 milliwatts per square centimetre when displaying video and around 0.5 milliwatts per square centimetre for still images.

"What I like about this work is it is both fast enough to support video while keeping energy use to a minimum. That's because once elements are switched, they stay switched without having to refresh them," says Jeremy Baumberg at the University of Cambridge.

For over half a million investors, *the penny's dropped.*

Pay a low flat fee instead of a percentage and keep the money you make.

interactive investor

i think, therefore ii.

Investment values can go up or down, and you may end up with less than you invest. Other fees and trading charges may apply, separate to monthly fee.

Green energy

A bright future for solar power

Solar electricity is growing rapidly and the planet could be powered on sunshine much sooner than you think, reports **Madeleine Cuff**

IS SOLAR power going to take over the world? The past few years have seen a frankly astounding acceleration in the rate of its deployment, with total generation capacity doubling between 2022 and 2024 to supply a full 7 per cent of the world's electricity. Just how high can that figure go?

The first six months of 2025 saw wind and solar together pass a historic milestone, generating more power than coal for the first time and making renewables the world's leading source of electricity. The driving force behind this "crucial turning point" in the energy transition, as UK-based think tank Ember described it, was the growth of solar. It accounted for 83 per cent of the total increase in the world's electricity demand in 2025, according to Ember's analysis, and has been the largest source of new electricity globally for three years in a row.

Solar's secret weapon? How cheap it is. It is the world's lowest-cost electricity, with the price of installing a solar system dropping by 90 per cent over the past 15 years. "Right now, silicon panels themselves are the same cost as plywood," says Sam Stranks at the University of Cambridge.

In other words, we have a plentiful and cheap source of electricity that can be built quickly, almost anywhere in the world. Is it fanciful to imagine that solar could one day power everything?

At the most fundamental level, the supply of solar energy to Earth is almost limitless. Even once you factor in the efficiency rates of modern solar panels, supplying all of the world's energy needs with the sun's power would require around 450,000 square kilometres of land, a 2021 report from UK think tank Carbon Tracker estimated.

COSTFOTO/NURPHOTO VIA REUTERS

Solar power is generating more of the world's electricity than ever

90%
The drop in the cost of solar panels over the past 15 years

0.3%
The global land area that may be required to supply the world's energy needs with solar power

80%
How much of the world's electricity could be generated by solar power by 2100

That's just 0.3 per cent of global land area.

Kingsmill Bond, one of the report authors who is now at Ember, says that while there are trade-offs when it comes to land use – solar may compete with agriculture, for example – for most countries, there is plenty of space to deploy these technologies.

A new generation of panels

The question, then, is what is stopping solar power from taking over the global electricity supply entirely? The first issue is that of efficiency. Silicon photovoltaic panels, which make up the bulk of the global solar market, currently convert about 20 per cent of the sun's energy into electricity. By comparison, hydropower plants convert 90 per cent of the potential energy into electricity, wind turbines about 50 per cent and fossil fuel plants 30 to 40 per cent.

In real terms, this means you need many more solar panels to provide the same amount of power that you could harvest from other sources. That's why solar firms and scientists are hard at work trying to unlock more efficiency gains from solar panels, in the hope that an efficiency boost will deliver a double win for solar: even lower system costs and less demand for land.

However, crystalline silicon panels are nearing the limits of the efficiencies they can achieve, with best-in-class cells now at about 25 per cent efficiency. "The practical limit for crystalline silicon is probably about 28 per cent," says Jenny Nelson at Imperial College London.

Pushing efficiencies above that will require a shift to what is known as a tandem solar cell, which introduces a second semiconductor to increase the amount of energy a cell can extract from the solar spectrum. Tandem silicon-perovskite cells

are seen as the most promising option, with a theoretical efficiency limit of about 50 per cent. Real-world tandem panels won't achieve anything like that level of efficiency, but could reach 35 to 37 per cent efficiency, says Stranks.

After years of research, the first tandem silicon-perovskite solar panels are just starting to enter commercial production, and they need to be tested by industry to see how long they maintain their performance under real-world conditions. But Stranks is optimistic about their potential. He estimates that in 10 years' time, they will become the dominant technology on the market. "On the face of it, they wouldn't actually look that different from the roof or on the street, but they are producing 50 per cent more power than today's panels," says Stranks. "It's a big change."

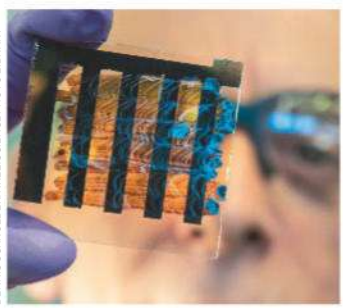
Not only would greater efficiency cut costs even further, but it could also unlock new deployment opportunities, he says. For example, high-efficiency panels could enable solar roofs on electric cars, allowing their batteries to charge during the day. The stored power could then either be used for transport or discharged to the home for use during the evening, he suggests.

Solving storage

Such innovation could help to untangle one of the other major issues with solar power: its fickleness. The sun, of course, doesn't shine all the time. For countries in the "sun belt", including India, Mexico and many African nations, this is less of a problem, as the sun shines almost all year round and batteries can be used to store excess energy during the day for use in the hours after dark. This solar-plus-storage set-up is becoming increasingly cost-effective, with the cost of lithium-ion batteries dropping by 40 per cent in the past two years alone, according to BloombergNEF.

"Ultimately, the only advantage that fossil fuels have over sunshine as a source for electricity is their storability," says Bond. "And, suddenly, that storability issue has been solved for 90 per cent of the time by a single technology, which is the battery."

But for countries further north, where winter days are short and grey, it is a different story. "[Solar] is an unbelievably, amazingly good energy source, with zero pollution, rapid payback of energy investment – it just ticks every single box," says Andrew Blakers at the Australian National University in Canberra, Australia. "Unless you live in northern Europe, north-east Asia or the north-east United States, where you have plenty of sun in summer and not much in winter, [solar] is simply the best."



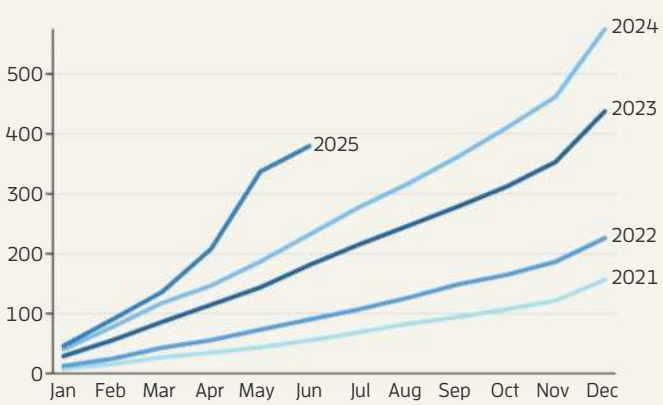
DENNIS SCHROEDER/NREL/SCIENCE PHOTO LIBRARY

Pervoskite cells could make solar panels even more efficient

"Greater efficiency would not only cut costs further, but could unlock new deployment opportunities"

The rate of solar panel installations keeps rising each year

Global solar capacity additions, cumulative by year in gigawatts



SOURCE: EMBER

For countries that have long, dark winters, wind power can step in to fill much of the gap, says Blakers. But energy storage solutions that can bank power for weeks or months at a time will also be needed. Such "interseasonal storage" is still in its infancy, with few solutions operating at commercial scale. But pumped hydro, hydrogen and compressed air storage could all provide an answer to this conundrum. Blakers's prediction? "Batteries take care of the short term, pumped hydro takes care of the long term," he says.

Political headaches

If anything, efficiency and storage are the easy problems to solve. "I think the bottlenecks probably lie in politics, consistency in policy, regulation, vested interests of other industries," says Nelson.

The climate-sceptic Trump administration in the US is a case in point. Earlier this month, federal officials cancelled a huge proposed solar project in Nevada that would have been one of the largest schemes in the world, just the latest in a series of actions to curtail solar funding programmes and block projects.

But Bond believes the transition to renewable power is now all but unstoppable given its economic advantages over traditional generation sources. "Incumbents can hold back the tide for solar in individual countries and individual projects and individual years," he says. "The current Trump administration is doing its very best to slow down the current deployment of renewables. But all it really means is that they then fall behind in the global race to deploy superior technology."

Blakers agrees, adding that solar energy may be the only ›

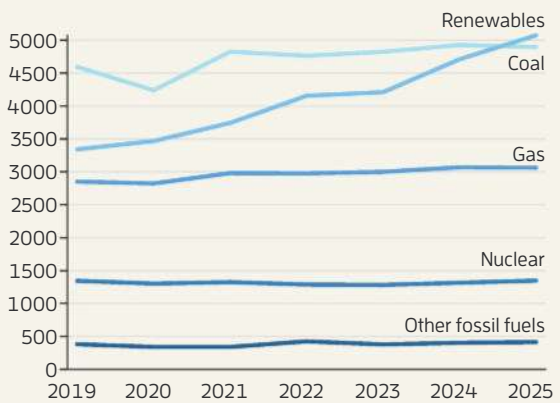
way to meet fast-growing power demand from AI data centres. "Even in the US, it's difficult to see solar being turned off even by a determined federal government, because many states like it, and it's by far the quickest way to get large amounts of energy," he says.

The other major bottleneck for clean energy is logistical. Existing electricity networks need to be rewired to cope with huge, fluctuating supplies of electricity coming from new areas. A more flexible grid, which can cope with surges in generation and even tweak power demand in response, will help maximise the use of green power. But delivering these grids of the future costs money. In the UK alone, energy companies plan to spend £77 billion over the next five years refitting the transmission network to cope with the shift to wind and solar.

In lower-income nations, where grid networks aren't yet so comprehensive, countries can move more quickly to build renewable-friendly infrastructure from the get-go, allowing renewables to penetrate further into grid supply. The 10 so-called BRICS nations – Brazil, China, Egypt, Ethiopia, India, Indonesia, Iran, Russia, South Africa and the United Arab Emirates – now collectively account for more than half of the world's electricity generation from solar, according to Ember.

Renewables produced more electricity than coal for the first time on record in the first half of 2025

Global electricity generation, Jan–Jun of each year in terawatt-hours



SOURCE: EMBER

"We've found this cheap, universal energy source – of course we are going to figure it out"

A wider challenge for countries is to electrify greater chunks of their energy demand, from heating to transport. Such progress is crucial to cut fossil fuel use in other parts of the global economy. As Nelson puts it: "If we want to decarbonise the planet, then we need to electrify first." Here, too, lower-income nations are racing ahead of higher-income ones. China's share of electricity in final energy consumption hit 32 per cent in 2023, far outstripping the 24 per cent electrification rate of the US and richer European nations, according to Ember.

A solar future?

Despite the success this year, the technical, logistical and political challenges outlined above may slow the rollout of solar in some countries in the short term. Earlier this month, the International Energy Agency predicted that renewable power will more than double by the end of the decade, but is set to fall short of an international goal to triple capacity by the same date. The agency said policy changes in the US and the challenges of integrating solar into grid systems were headwinds to the expansion in renewables capacity.

But energy market experts are confident that, by 2050 and beyond, solar will dominate global energy supply. "By the end of this century, it is pretty clear that we will be getting all of our electricity from renewable sources, of which the vast majority will be solar," says Bond, estimating that as much as 80 per cent of the world's electricity supply will be generated by solar by 2100. Added to that, at least 80 per cent of the world's total energy demand will be electrified, he expects.

Roadblocks from politics, energy storage and infrastructure will all be cleared out of the way to usher in the green power revolution. "The human condition is to turn energy into stuff," says Bond. "We use energy for everything. And now, suddenly, we found this cheap, universal energy source – of course we are going to figure it out." ▮

Some people resist solar power, while others have embraced it

MICHAEL SILUK/ALAMY

COSTFOTO/NURPHOTO VIA GETTY IMAGES

Health

Is this how breastfeeding fights cancer?

Rise in immune cells may explain why we see a lower incidence of breast cancer after breastfeeding

Larissa Fedunik

BREASTFEEDING has long been linked to a reduced risk of breast cancer, but it isn't entirely clear how it has this effect. Now, scientists have found that women who have breastfed have more specialised immune cells in their breasts.

Previous research suggests the risk of breast cancer – the second most common form of cancer in the world – is reduced by 4.3 per cent for every year of breastfeeding.

The reasons why aren't fully understood, but changes to breast tissue and hormonal exposure are thought to be involved. To learn more, Sherene Loi at the Peter MacCallum Cancer Centre in Victoria, Australia, and her colleagues analysed breast tissue from 260 women, aged between 20 and 70, of a diverse range of ethnicities. The women varied in the number of children they had, if any, and if they reported having breastfed, but none had ever been diagnosed with breast cancer.

"We found that women who have breastfed have more specialised immune cells, called CD8+ T-cells, that live in the breast tissue for decades after childbirth," says Loi. "These cells act like local guards, ready to attack abnormal cells that might turn into cancer." In some cases, these cells stayed in the breasts for up to 50 years.

The team then looked at mice, some of which had completed a full cycle of pregnancy, lactation and mammary recovery during pup weaning. Their breast tissue was analysed 28 days later, when their mammary glands had returned to a pre-pregnancy state. Other mice had their pups removed shortly after birth or had never been pregnant.

The researchers found that completing a full cycle of lactation was linked to a significant increase in specialised T-cells accumulating in mammary tissue, which didn't occur in the other mice. They then implanted triple-negative breast cancer cells, an aggressive form of the condition, into the mice's mammary tissue and found that those that had experienced a full cycle of lactation had far slower tumour growth. But when the the CD8+ T-cells were depleted, the tumours grew very quickly.

PIERRE VERDY/AFP VIA GETTY IMAGES

Women gather at an event to promote breastfeeding in Paris, France

Next, the researchers studied clinical data from more than 1000 women who had been diagnosed with triple-negative breast cancer after at least one full-term pregnancy. They found that those who reported having breastfed had tumours with higher CD8+ T-cell density (*Nature*, doi.org/qbdb). "This suggests there was ongoing immune activation and regulation from the body against their breast cancer," says Loi.

After adjusting for other risk factors linked to breast cancer-related deaths, they found that the women who breastfed lived significantly longer overall.

The researchers think T-cells accumulate in the breasts during breastfeeding to prevent infections that may lead to mastitis. But Loi stresses the decision of whether to breastfeed is an individual's choice and may not prevent breast cancer.

Daniel Gray at the Walter and Eliza Hall Institute of Medical Research in Victoria says this analysis, "lays the foundation for future work that might explain how the CD8+ T-cells retain a 'memory' of breastfeeding". ▮

Chemistry

Why coffee beans extracted from civet poo are so delicious

COFFEE beans collected from the faeces of civets have a unique chemistry that may explain why such beans are prized for their flavour.

Asian palm civets (*Paradoxurus hermaphroditus*) are mongoose-like animals native to South and South-East Asia. Civet coffee, also known as kopi luwak, is one of the world's strangest luxury beverages. The beans sell for up to $1000/kg. However, animal welfare groups accuse the industry of keeping civets caged in terrible conditions.

To learn how coffee beans are transformed after passing through a civet, Palatty Allesh Sinu at Central University of Kerala, India, and his colleagues collected coffee samples from five coffee-growing farms near Kodagu in the Western Ghats mountain range of India. Civets live wild within these farms, none of which keeps them caged.

The researchers obtained nearly 70 civet scats containing coffee beans and also manually harvested beans from the plantations' robusta coffee trees, before running a suite of tests that looked at key chemical components, like fats and caffeine.

Total fat was significantly higher in the civet beans than in those from trees, while caffeine, protein and acid content were slightly lower (*Scientific Reports*, doi.org/qbd9).

KURIT AFSHEN/SHUTTERSTOCK

Asian palm civets are nature's best baristas

The team suggests that the higher fat content in civet coffee may contribute to its unique aroma and flavour profile, and the lower level of proteins may result in decreased bitterness.

Sinu says caging civets is cruel, and hopes to develop artificial fermentation processes. "Once we know the enzymes involved in digestion and fermentation, we may be able to artificially make civet coffee," he says. ▮

James Woodford

Genetics

Gene editing protects pigs from deadly virus

Michael Le Page

A TINY genetic tweak can make pigs completely resistant to classical swine fever, a major problem for farmers around the world. The same gene edit should also make cattle and sheep resistant to related viruses that plague livestock.

The widespread use of gene-edited pigs resistant to classical swine fever would improve animal welfare and increase productivity, which should lower greenhouse gas emissions and cut prices in shops. "It would help towards sustainable livestock production," says Helen Crooke at the UK's Animal and Plant Health Agency.

Classical swine fever is a highly contagious viral disease that causes everything from fevers to diarrhoea and miscarriages, and can kill large numbers of pigs.

Although the disease has been eliminated in many regions, it occasionally re-emerges. Six million pigs were culled to halt an outbreak in the Netherlands in 1997, for instance, while Japan has been struggling to re-eliminate the disease since 2018.

Where the disease is present, vaccines containing live, weakened strains of the virus are used to protect livestock, but this is laborious and expensive. "Vaccination takes a lot of coordination and monitoring," says Christine Tait-Burkard at the University of Edinburgh, UK.

Countries that vaccinate pigs cannot export to regions that are free of the disease. And any disruption to vaccination can lead to outbreaks.

But the classical swine fever virus has an Achilles heel. A bunch of the virus proteins are made as a single long strand of amino acids that has to be cut into pieces to become functional, and it relies on a pig protein to do the cutting.

SIMON LILLICO

These pigs are now resistant to classical swine fever

Changing a single amino acid in this pig protein, called DNAJC14, can block the cutting. So, Tait-Burkard and her colleagues used CRISPR gene editing to create pigs with this tiny change.

The team then sent some of the pigs to a secure facility, where Crooke and her colleagues sprayed live swine viruses into their noses. None developed any signs of infection – no symptoms, antibodies or detectable viruses – whereas normal pigs all fell ill (*Trends in Biotechnology*, doi.org/p986).

> "Gene editing pigs to be resistant to classical swine fever would aid sustainable livestock production"

"These animals were completely resistant to replication of the virus and remained happy and healthy throughout the study," says Crooke.

The work was partly funded by an international breeding company called Genus, which is now considering whether to commercialise the pigs.

Where gene editing is used to make tiny changes that could occur naturally, many countries are regulating it less strictly than conventional genetic engineering. Japan has already approved three gene-edited fish.

England is due to start approving gene-edited plants soon, but has yet to finalise the rules for livestock. These rules will almost certainly require that gene edits don't affect welfare.

The team hasn't seen any adverse effects in the pigs that are resistant to classical swine fever, says Simon Lillico, a team member at the University of Edinburgh, but further studies will be needed to confirm this.

Viruses very closely related to classical swine fever cause bovine viral diarrhoea in cattle and border disease in sheep. The cattle and sheep diseases are less deadly, but they still affect welfare and productivity. The Edinburgh team is now investigating whether the change made in pigs will work in cattle and sheep too. ▮

Technology

Hand-powered device disinfects drinking water

James Woodford

A SIMPLE jar with a cranked handle could revolutionise the provision of clean drinking water.

In off-grid communities and disaster zones, traditional water purification isn't reliable, so Xu Deng at the University of Electronic Science and Technology of China in Chengdu and his team invented a device that can disinfect water with a minute of easy, manual stirring.

Their solution is based on spherical silica nanoparticles coated with amine group chemicals, which are positively charged in water, and gold nanoparticles, which become negatively charged in the stirred water.

"Think of a hand-cranked jar with a small dose of engineered, sand-like powder," says Deng. "A few turns of the handle creates gentle shear in the water, and that motion 'wakes up' our nanoparticles."

The flow of water on the surface of the gold and amine nanoparticles create an electric charge, leading to the formation of oxidising chemicals called reactive oxygen species. "Those reactive oxygen species punch holes in microbial membranes, so pathogens can't survive or reproduce," says Deng. "When you stop stirring, the powder separates from the water on its own, and you draw clean water from the outlet."

The team tested the device on 16 highly transmissible pathogens that pose a serious public health risk. It achieved a 99.9999 percent reduction in *Escherichia coli* with just 15 seconds of stirring the water at 50°C, and the same reduction in *Vibrio cholerae* within 1 minute (*Nature Nanotechnology*, doi.org/p974). Overall, it inactivated more than 95 per cent of all the tested microorganisms.

The device is still in its proof-of-concept phase, says Deng, so they haven't yet determined how many litres of water can be disinfected. ▮

Health

How antidepressants affect the body

These drugs have a range of physical side effects – knowing which could help inform prescriptions

Chris Simms

ANTIDEPRESSANTS vary greatly in their side effects – from weight gain to weight loss and blood pressure changes. This may need to be taken into account when doctors decide which drug is best for each person.

About 1 in 10 people in Europe and the US take antidepressants for conditions such as depression and anxiety. Research earlier this year found withdrawal symptoms may be less common than we thought. But there can also be a range of physical side effects when taking these drugs. It just isn't clear which drug causes which effect.

To find out more, Toby Pillinger at King's College London and his colleagues analysed results from 151 randomised-controlled trials and 17 US Food and Drug Administration reports. These covered 30 antidepressants whose effectiveness and side effects were compared against placebos over around an eight-week course of treatment for various psychiatric conditions.

They found some drugs were linked with weight loss and others with weight gain. Maprotiline, for example, was associated with an average weight gain of about 1.8 kilograms, whereas agomelatine was linked to losing about 2.4 kg (*The Lancet*, doi.org/p97v).

The study also showed that the drug fluvoxamine was linked to heart rate slowing by 8 beats per minute (bpm), on average, but nortriptyline increased it by 13 bpm. The latter also cut systolic blood pressure – your blood pressure when your heart is contracting – by between 3 and 7 millimetres of mercury (mmHg), while doxepin pushed it up by almost 5 mmHg, which could have knock-on effects on overall health. "Each 1 mmHg increase in your blood pressure, if you have high blood pressure, increases your risk of a stroke by 1 per cent," says team member Oliver Howes.

Other drugs, such as paroxetine, duloxetine and venlafaxine, were associated with increases in cholesterol. Whether these side effects worsen, improve or plateau beyond eight weeks is unclear.

Of the more than 92 million doses of antidepressants prescribed in England last year, about 85 per cent were either sertraline, mirtazapine, fluoxetine, amitriptyline, citalopram or venlafaxine. Amitriptyline was seen to increase weight, heart rate and blood pressure, while venlafaxine raised heart rate, blood pressure and cholesterol. The other four were found to have a relatively good profile for most of the examined factors

"It's all about finding the right molecule for the right person and engaging in personalised prescribing"

Pillinger's team is developing a digital tool for medics with a drop-down menu of an antidepressant's common side effects. "It's all about finding the right molecule for the right person and engaging in personalised prescribing," he says.

But John Ioannidis at Stanford University in California says the results may be biased if the team only included studies that showed side effects. He also says longer-term studies are needed, as people generally take antidepressants for longer than eight weeks.

Pillinger says there is "always the risk of bias", but he is "relatively confident that we have gathered most of the data that is out there". His team is also working on an analysis of longer-term studies.

People on antidepressants who are worried about side effects shouldn't stop their treatment, though, says Howes. "If they are concerned, this is something that we would recommend that they talk to their doctor about." ▮

Robotics

Teenager builds advanced robot hand from Lego

A ROBOT hand built from Lego pieces by a 16-year-old and his father can grab and move objects, displaying similar qualities to a leading robotic hand.

Jared Lepora, a student at Bristol Grammar School, UK, started work on the hand when he was 14 with his father, Nathan Lepora, who works at the University of Bristol.

The device borrows principles from cutting-edge robotic hands, including the Pisa/IIT SoftHand, but uses only off-the-shelf parts from Lego Mindstorms, a line of educational kits for building programmable robots.

"My dad's a professor at Bristol University for robotics, and I really liked the designs [of robotic hands]," says Jared. "It just inspired me to do it in an educational format and out of Lego."

The hand is driven by two motors using tendons, and each of its four fingers has three joints. A differential made from Lego clutch gears links the digits so they move together until they touch something, then stop, similar to how we grasp objects.

In tests, the Lego hand successfully grasped nine household items, including a plastic cup and bowl, as well as a soft toy weighing 0.8 kilograms (arXiv, doi.org/p983).

A single finger on the hand can close fully in about 0.84 seconds and open in 0.97 seconds – around half as fast as a 3D-printed equivalent of the Pisa/IIT SoftHand using metal bearings. In static tests, a finger on the Lego hand could bear 5 newtons of load and push 6 N of weight, and had 1.8 N of closing force. By comparison, the 3D-printed version could produce 8 N of load-bearing force, 7 N of weight-pushing force and 2 N of closing force.

NATHAN LEPORA

Jared Lepora holding the robotic hand that he built entirely from Lego pieces

"You're never going to get a hand that's as good [as a 3D-printed hand] in terms of its capabilities with a hand made out of Lego," says Nathan. The Lego hand is also much bigger: each digit is 145 millimetres long and 30 millimetres wide.

Lego Mindstorms was discontinued in 2022, but Jared says the device can still be updated with different Lego pieces. ▮

Chris Stokel-Walker

Leave a cancer breakthrough in your Will.

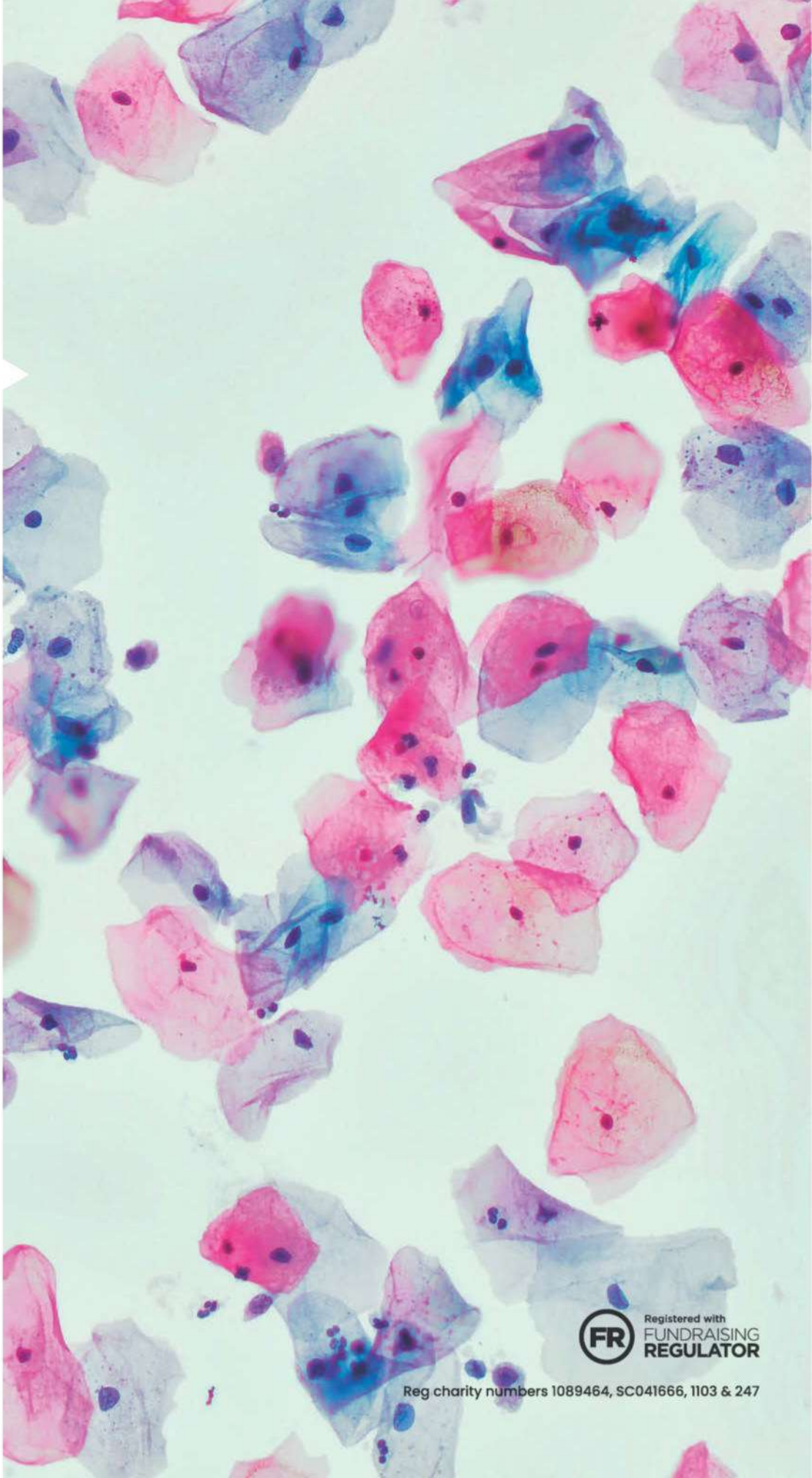
Our research led to the creation of the HPV vaccine, which prevents the virus that causes nearly all cervical cancer cases. Vital protection for millions every year, made possible with support from gifts left in Wills.

Gifts in Wills fund over a third of our work to beat cancer.

Find out more:
cruk.org/giftsinwills

CANCER RESEARCH UK

Together we are beating cancer



Registered with FUNDRAISING REGULATOR

Reg charity numbers 1089464, SC041666, 1103 & 247

Views

The columnist
Chanda Prescod-Weinstein laments US science retreat p22

Aperture
Purr-fect pics explore the world of our feline friends p23

Culture
New book ponders the origins of life and abstract thought p26

Culture column
Simon Ings finds nature doc *Super Nature* charming p28

Letters
Could mental illness's roots lie in planning for the future? p29

Comment

Climate compromises

COP's negotiations will focus on money for climate change adaptation, but some tough choices lie ahead, warns **Susannah Fisher**

HEATWAVES, flooding, storms and droughts driven by climate change are making life more difficult for people around the world. Societies will need to adapt to these changes, but governments, businesses and individuals won't be able to afford to protect everywhere, nor will many people want to live with high levels of risk.

As I argue in my new book, *Sink or Swim*, we need to face up to a series of hard choices about how to best adapt to this new world. Such choices include where we can live safely, who makes those decisions and how we shift the global food system to meet everyone's needs in times of scarcity.

Negotiators at COP30 in Brazil later this month will focus on mobilising finance to help low-income countries reduce their emissions and adapt to the impacts of climate change.

At the annual UN conference last year in Baku, Azerbaijan, governments agreed to mobilise at least $300 billion by 2035 and to aim for up to $1.3 trillion through public and private sources. But many high-income countries aren't contributing their fair share, and UNEP estimates that the funding gap for adaptation in lower-income countries is $187 billion to $359 billion per year.

More money is essential, but even a big increase won't be enough on its own to manage the risks the world faces. As I have seen in my own work on adaptation with governments and civil society, adaptation efforts have so far often been small-scale and incremental. Measures like early-warning systems, cooling spaces and flood barriers are important and can help – for now. But this approach will not be enough to adapt to the impacts we are facing, such as heatwaves, flooding, crop failures and potential ecosystem collapse, and we will need address the tough questions ahead.

ELAINE KNOX

One of these hard choices will be when and how to relocate communities away from low-lying coastlines. There are examples of planned relocation in many places, including China, Fiji, India, Japan, the Philippines and the US. But it is really hard to do well. Residents in Wales learned from the local media that the sea defences around their town wouldn't be maintained in the future, but many more places in the UK are at risk.

Governments will need ways to choose which places to defend in the face of sea level rise and flooding, and which places will require retreat. In each of these sites, we will need consultations that allow communities to identify what is important to them and support from the government to facilitate those who have to move.

Another hard choice will be how to balance diversity and productivity in the food system to make sure there is both enough resilience to withstand shocks and also enough food to feed a growing global population. The food system is especially vulnerable to climate change, as there is so little diversity within it. Huge quantities of staple crops are grown in a few areas of the world and limited varieties dominate global consumption. A diverse system, with more redundancy built in, would be more resilient, but there are difficult decisions ahead in order to build this, and tradeoffs with efficiency and productivity.

Governments will need to invest in or subsidise more diverse food varieties and support local food systems, and establish a wider range of trading relationships. This would have higher short-term costs, but more long-term benefits when shocks hit.

Addressing difficult decisions like these, as well as in areas like migration, water use and biodiversity, will require high levels of public and private investment as well as trade-offs, compromises and short-term political costs.

But without facing up to what needs to be done, we risk consigning ourselves to the chaos of the climate crisis in perpetuity. ▮

Susannah Fisher is author of *Sink or Swim: How the world needs to adapt to a changing climate*

Field notes from space-time

Looking backwards The US's decision to stop supporting a telescope that would have given us unprecedented insight into the early universe is devastating, says **Chanda Prescod-Weinstein**

Chanda Prescod-Weinstein is an associate professor of physics and astronomy at the University of New Hampshire. She is the author of *The Disordered Cosmos* and the forthcoming book *The Edge of Space-Time: Particles, poetry, and the cosmic dream boogie*

Chanda's week

What I'm reading
I have been enjoying Niayesh Afshordi and Phil Halper's Battle of the Big Bang: The new tales of our cosmic origins.

What I'm watching
I have been rewatching DC Universe films that feature Harley Quinn, a personal favourite.

What I'm working on
I have been trying to capture good images of the Andromeda galaxy from my backyard.

This column appears monthly. Up next week: Leah Crane

ROBERT FROST's poem *The Road Not Taken* opens with "Two roads diverged in a yellow wood,/ And sorry I could not travel both".

These lines come to mind when I consider the US government's public letter of 9 July stating that it would no longer support the CMB-S4 project. CMB-S4, short for Cosmic Microwave Background-Stage 4, was meant to be a next-generation, multi-continental telescope facility that would have given all of humanity unprecedented insight into the earliest light to ever fly free through the cosmos.

In the beginning, the universe was full of a dense particle-plasma stew. The plasma was so dense that particles of light, photons, couldn't go very far without running into something. As well as being thick, the stew was very hot, which prevented the formation of phenomena like atoms. Only after the universe had experienced cosmic inflation, where space-time expanded rapidly for an almost negligible fraction of a second, did it cool off enough for the first hydrogen atoms to form. Once this kind of clumping became possible, photons had room to manoeuvre and began to fly across space-time.

It was 61 years ago that humanity first learned we were awash in these photons, which came to be known as the cosmic microwave background radiation. What seemed like a bit of background noise in a radio signal turned out to be a messenger from the early cosmos. For decades, we have scrutinised these photons: their wavelength (and associated temperature), their intensity and their variation across space.

The CMB is almost a literal gold mine, in the sense that it provides a lot of information about where everything we can see came from, including the stars whose explosions make gold. If we scan the entire sky and look at the temperature associated with the photons, we see small variations in the temperature. Their locations are random, but the size of the variation is consistent across them all.

Our best cosmological theory tells us that these fluctuations are the result of little quantum variations in how much stuff there was at any given location at the moment the photons went free. Places where there was a little bit more were essentially the starting point of gas that gravitationally accumulated into protostars, which became stars that clustered together into what eventually became galaxies. So, those little variations in the CMB are the beginning of us.

> **"The pullback from the project is part of the US's reckless retreat from global science collaboration"**

Perhaps the single most important measurement we have done of the CMB is characterising how these temperature variations correlate with physical scale. We can ask how many of the variations are due to effects on larger scales or smaller scales, knowing that certain physical phenomena happen at longer distances and others at shorter ones. In other words, different moments in cosmological history are imprinted on the CMB.

For example, we can "see" when the universe became transparent to matter – that first moment when hydrogen formed, an instant known as recombination. We can also "see" how much dark matter and dark energy there is in the universe, even though they are invisible to us. Their existence is imprinted on the CMB.

CMB-S4 was supposed to be the next step in uncovering all of the lessons that the CMB has to teach us. One major goal was to look for evidence of primordial gravitational waves – ripples in space-time caused by cosmic inflation. "Inflation" is really a class of models, and we know that, broadly, they all give the right physics for our universe. But we are still unsure about the details. Because inflation happened in the universe's earliest moments, imprints of gravitational waves on the CMB are likely to be the best way to distinguish between inflationary models.

The end of governmental support for CMB-S4 is like putting a stick in your own bicycle wheel: we were flying along, joyfully studying the cosmos, and now we have been thrown entirely. The impact will be felt globally too. Historically, the US has invested more into cosmological science than most nations, which is one reason why students from around the world come to the US to study. The data from US-funded experiments has also often become a global resource, so the pullback from this project, which already seemed likely under the previous presidential administration, is now part of the US's reckless retreat from global collaboration.

Frost ends his poem by talking about his choice of road: "I took the one less traveled by,/ And that has made all the difference." It is so unfortunate that, when it comes to CMB science, the US decided not to take the road less travelled. It will certainly make a difference, but not for the better. ▮

New Scientist
Subscriber Benefits

LIVE LECTURE + Q&A

Subscriber event

Beyond reality: What are we truly made of?

Online, 25 November 2025 | 6-7pm GMT / 1-2pm EDT

Join particle physicist Kate Shaw for an exclusive virtual tour inside the greatest scientific instrument ever built: the Large Hadron Collider (LHC) at CERN. By smashing matter together at nearly the speed of light, the LHC acts as a time machine, allowing us to glimpse the early moments of the universe.

Discover:

- What holds our universe together and how it all began, from the big bang to the present day
- The significance of the Higgs boson discovery and its role in explaining why matter has mass
- The search for dark matter and other mysterious phenomena that hint at a new layer of physics

Kate Shaw, experimental particle physicist, working on the ATLAS experiment at CERN and the Deep Underground Neutrino Experiment (DUNE) at Fermilab

Scan me to register

Register for free
newscientist.com/beyond-reality

To register, use your 12-digit subscriber number, which can be found on customer service and event emails from us, or above your address on your print copy.

Cats do the funniest things
Tim Flach reveals more about the science behind cat cuteness at **newscientist.com/video**

Cat's eye view

Tim Flach
Abrams

CATS are distinctive animals: domesticated for centuries, they have been revered and reviled in equal measure throughout history and bred to match our own aesthetic tastes and whims. Renowned animal photographer Tim Flach explores their world in his new book *Feline*, showing how intertwined our lives have become with theirs.

"At the heart of this project was to unmask the essence of feline," says Flach. Including more than 170 of Flach's cat images, *Feline* also sees neuroscientist Morten Kringelbach explore why we find cats so compelling, and evolutionary biologist Jonathan Losos delve into the species *Felis catus* and its evolution.

Pictured at the far left is Stella, a Cornish Rex from Montreal, Canada, whose striking appearance is a result of genetic quirks during her embryonic development. Cats with different-coloured eyes almost always have one blue eye, writes Losos. The phenomenon is particularly common in entirely white cats.

Flach's images also reveal how cats are perfectly adapted for a life of hunting for prey – as demonstrated here by this 8-week-old Sphynx cat, Valentine, at near left, leaping for a cat toy that is just out of sight.

"I've come to appreciate that cats embody a quiet wildness that connects us to a time before modernity, reminding us of a natural world unburdened by human complexities," writes Flach in his prologue to *Feline*. "A cat is never owned, only accompanied."

David Stock

Finding a path through

Can sea slugs form abstract thoughts? Do we dare to see any "purpose" in evolution? **Thomas Lewton** explores a bold, provocative book

Book

One Hand Clapping
Nikolay Kukushkin
Swift Press (UK); Prometheus Books (US)

"IF TWO hands come together and make a sound, what is the sound of one hand clapping?"

Meditate on this Zen Buddhist koan (a paradox used to train Zen Buddhist monks) long enough, promises neuroscientist Nikolay Kukushkin at the start of his book, and the origins of mind, and perhaps even human experience, will become clear.

But as many Buddhists also know, the path to enlightenment is long and difficult, even if it is ultimately rewarding, and *One Hand Clapping* is no different.

First published in Russian, the book has been translated into English by its author, now at New York University. In it, Kukushkin explores the origins of life and its evolution along wonderfully diverse branches. He encourages us to think about origin stories, not in any crudely reductionist manner, but in terms of what he calls nature's ideas or essences.

Being savvy to the nuances of such words, Kukushkin is clear: "Don't call it an *idea* if you think that's too spooky or unscientific – call it an *essence*, nature's idea: a rational fruit of selection." He connects this to Plato, who called nature's idea's *eidos,* or essences.

Using this filter, hydrothermal vents (his favoured location for life's origin) aren't just porous rocks and flowing fluids, but also patterns of activity that pop up throughout nature. There is, for instance, a tendency for beings to become complex by tapping into more energy – a dynamic common in deep sea vents,

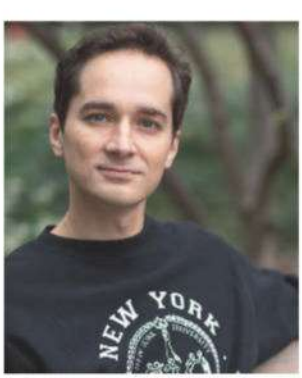
NIKOLAY KUKUSHKIN

***Aplysia californica* (above) in the lab of neuroscientist Nikolay Kukushkin (below)**

photosynthesising cells and humans burning fossil fuels.

Other essences highlight motion and freedom, or the distinction between wanting and liking. But I found that Kukushkin's research into the sea slug *Aplysia californica* provided the clearest example of their power, as he explored how the humble slug created an abstract idea vital for its survival.

This takes the book a few pages, but it involves the interaction of sensory and motor neurons, and muscles and the siphon, a key breathing organ on the slug's back. Each of the neurons' activities has "different meanings", writes Kukushkin, like "touch to the tail" or "touch to the body regardless of location". As the slug learns where danger is likely to come from (and given that the siphon must always be protected), it uses the abstraction of "dangerous touch regardless of location" to make good choices.



ARINA VORONOVA

Kukushkin reasons that while human minds are more complex, similar pattern-finding and abstraction is the basis of our thinking. On top of these simple abstractions, we layer more that drive all aspects of our experience, from vision to language.

One Hand Clapping covers a lot of ground, which can make it seem like an entertaining lecture series, with amusing sketches. Some may find Kukushkin's playfulness a bit much. But stay with it.

Modern scientists tend to shy away from attributing rationality or creativity to biological or chemical systems, and from notions of agency or direction in life. Kukushkin reminds us the ancients had no such issues. And recently, among some biologists, there has been a resurgence of the idea that evolution happens, in some sense, "on purpose".

Scientists may fear this sounds like pseudoscience, or the "intelligent design" of religious groups. But we may need to revisit concepts we find uncomfortable by association – particularly when tackling existential questions like the origins of life and mind.

We are made of the same stuff as the physical world, yet there is something about subjective experience that seems profoundly different – the "hard problem" of consciousness.

For Kukushkin, the answer lies in the long arc of *eidos,* from atoms to cells and brains, objective in that they are "out there". We tend to think of abstractions, however, as internal and subjective. "What if," he asks, "the subjective is just a complicated form of the objective? What if all ideas... are essences?"

"Kukushkin encourages us to think about life's origin stories in terms of what he calls nature's ideas or essences"

This is a neat attempt to reason that objective and subjective are two sides of the same coin. If you think about it long enough, Kukushkin assures us, the hard problem dissolves. Personally, I don't buy it: the phenomenal quality of conscious experience that binds together our senses, emotions and thoughts makes more sense when reframed this way, but I struggle to see how it can entirely bridge the gulf between subject and object.

Perhaps we will never resolve this. But for now, at least, *One Hand Clapping* is a welcome koan, in which "the process of getting to the meaning means more than the meaning itself". ▮

Escaping enshittification

A powerful book shows how algorithmic capitalism ends up ruining good services. What can we do, asks **Matthew Sparkes**

Book
Enshittification
Cory Doctorow
MCD Books

"ENSHITTIFICATION" is one of those rare new words that so perfectly sums up a prevailing but innominate concept that it feels like it has existed forever, like "shrinkflation" or "greenwash" before it.

We are all painfully familiar with websites or apps enshittifying – that is, getting worse over time – as their owners squeeze users for profit. This can be seen everywhere from Instagram ditching a chronological stream of friends' photos for algorithm-cobbled influencer nonsense to Apple preventing easy repairs and forcing you to buy a new handset.

Cory Doctorow coined the term in 2022 and has developed the idea in his latest book, *Enshittification: Why everything suddenly got worse and what to do about it*, which is also a call to action.

The playbook for enshittification

Does your phone seem less functional than it once was? It may be due to enshittification

HECTOR RETAMAL/AFP VIA GETTY IMAGES

is that a platform like Facebook sets up and offers a good service. It's useful and fun, and people flock to it. The company then waits until we are reliant on it – our friends, neighbourhood groups, swimming clubs and schools are all there – and leaving is simply too much hassle.

By this point, the user base is so vast that advertisers are locked in, too. That's when the firm starts to prioritise profits, making the service worse for users: more ads, more algorithms. Finally it squeezes its advertisers. The platform is now awful and toxic, works for nobody but shareholders and is impossible to leave. As Doctorow puts it, we are trapped in the rotting carcasses.

Years ago, the market would kill a bad company. If a café began to serve bad coffee, we would buy different coffee. But now tech firms carve out monopolies so profitable that they have huge resources to maintain them: buying competitors just to shut them down, lobbying politicians to weaken regulation and paying for exclusivity deals. (Did you know Google pays Apple $20 billion a year to make it the default search engine on Apple's Safari browser?)

***Enshittification* lays bare the open secrets of the industry, such as the companies that allegedly collect so much personal data they know to charge more for stuff on payday because we are less likely to quibble. Or those that use algorithms to suppress wages in the gig economy, or create keystroke-monitoring systems that alert managers if we stop typing.**

These distasteful snippets won't all be new to readers, but, consumed in bulk, they leave a bad taste in the mouth. They will even make the savvy kick themselves for the numerous and varied ways they are being misled.

Yes, the tricks are just companies doing what they are designed to do: extract as much profit as possible. But computers, algorithms and the internet have enabled ever-craftier and more complex techniques that were impossible even a decade ago, and things are wildly out of hand.

Doctorow warns that the regulators that are supposed to protect us are often weaker than the companies they oversee. But he also places a lot of faith in them being the solution.

There have been positive moves in the European Union and the US under President Joe Biden, although there is a great deal more to be done, and tech firms can dream up ways to do us down faster than they can be stopped. We can demand more from our politicians, and well-designed legislation backed by regulators with teeth can have some effect.

What isn't addressed, though, is the power of boycotting, and how tech firms need us more than we need them. It is completely possible to ditch social media, shop locally and use ethical search engines. And the more people who do it, the more likely it is that others will follow suit.

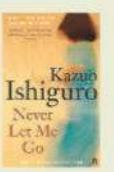
When it comes to travel, clothing or food, lots of us try to vote with our wallets. Maybe it is time more of us did it in the online world as well.

New Scientist *recommends*

Alison George
Features editor
London

This year is the 20th anniversary of the publication of Kazuo Ishiguro's renowned novel **Never Let Me Go** and I have finally got round to reading it.

I can hardly believe that such a haunting



story has been sitting on my shelf all that time, awaiting discovery. It is one of the best books I have ever read – and one of the most unnerving.

At first, Ishiguro's English boarding school setting seems so familiar. Then, slowly and obliquely, the cruel reality facing the young protagonists, Kathy, Ruth and Tommy, emerges.

But I'm not going to reveal any spoilers . For me, one of the most poignant aspects of turning the pages of this heartrending book was trying to work out what exactly was going on in this alternative, dystopian version of the 1990s.

Ishiguro's book has stood the test of time, not least because its exploration of what it means to be human is as pertinent today as it was 20 years ago.

The film column

True colours *Super Nature* is the ultimate home movie: a documentary stitching together local nature footage shot by pros and enthusiasts worldwide, using only the cheap 1960s film format Super 8. The result is ravishing, says **Simon Ings**

Simon Ings is a novelist and science writer. Follow him on X @simonings

NATURE HUNTER FILM LTD

Super 8 film captured this close-up of a silver-washed fritillary butterfly

ED SAYERS, a director of commercials and music videos, has a passion for Super 8, a motion-picture film format released in 1965 by Eastman Kodak. He's not alone: the dinky film cassettes survive because of the advocacy of a small global community of film-makers.

What marks Sayers out is his organisational ability. His first feature, *Super Nature*, which premiered at the London Film Festival last month, assembles Super 8 footage from 25 countries shot by 40 film-makers and local enthusiasts who captured the natural world near where they live.

When I read the premise of this movie, I will admit I was buckling in for 82 minutes of sparrows and house cats, but boy was I wrong.

While the film's distributor BFI is making much of its "green" credentials, what with it being a globe-spanning documentary that racked up precisely zero air miles, worthiness is a poor sales pitch. Better, surely, to emphasise how strange everything looks in this handheld, lo-fi format.

Super 8, says Sayers in voiceover, looks as though "someone had painted your memories for you". The literal truth of this becomes apparent as you settle into the medium's glare, flare, shakiness and shifts of hue and tone. The Super 8 world is closer to the one we see: it isn't polished, posed, well-lit or even perfectly focused, but nor is the world.

"Among many charming moments in the film is the observation that puffins 'have the kindest eyes'"

Yet it is often devastatingly beautiful, and so is this film. A few of the more ambitious shots featuring the smallest, fastest, most retiring creatures are hard to make out. But an animal isn't lesser because we only glimpsed it. The one sequence that didn't work for me was of migrating geese. While beautifully shot and edited, the set-up (microlights and two cameras) was too ingenious, too "staged". Better to lie in a puddle in the rain with a plastic bag over your head, filming a snail.

Big-budget nature film-making takes the diametrically opposite approach, revealing the world as the eye cannot possibly see it (or as it may not exist). The impulse to reveal new worlds is admirable – and I maintain that *Walking With Dinosaurs* is a joy – but I can't help wonder if viewers, drunk on perfectly lit, framed and timed marvels, wouldn't become jaded.

Super Nature shakes things up wonderfully. Structurally, it is built around the story of its making. Accompanying every sequence (of flamingoes, worms, coral and more) is each film-maker's voice, explaining what the footage means to them. Among many charming moments is the description of the sound puffins make as they run (clownish, as though they were wearing outsize slippers) and the observation that "they have the kindest eyes".

The testaments can be inspiring: some film-makers took to Super 8 because they needed a new way to see the world after misfortune had shrunk their lives to a point. Others trot out green pieties; a few should stick their heads under a cold-water tap (in ibex you can, apparently, see the wisdom of the mountains).

Then there is Sayers's own story. Act one: the director has a grand ambition – to record the natural world, using vintage tech and local film-makers. Act two: the director loses hope, editing footage of floods, fires, Ukrainian trenches and plastic garbage. Act three: the director is cheered and the project redeemed by a seal's playful antics.

It's as good a narrative frame as any, but perfectly predictable, in a way the footage never is. ▮

Film

Super Nature

Ed Sayers

In UK cinemas in 2026

Simon also recommends...

Film

The Silent World

Jacques Cousteau and Louis Malle

Though not the first to show the ocean depths in colour, Cousteau and Malle's 1956 documentary changed our view of two-thirds of the planet.

TV

Walking With Dinosaurs

Tim Haines

This six-part BBC documentary from 1999 (rebooted in 2025) brought scientific rigour to its unashamedly dramatic depictions of the Mesozoic Era.

Editor's pick

A new way to think about mental illness

18 October, p 6

From Ros Groves, Watford, UK

The fact that genetic developments linked to higher intelligence have been dated to around the time of a sudden explosion in the making of more complex tools would appear to be more than a coincidence.

What was required in a tool? How and where it would be used? How it could be adapted to suit changing circumstances? These all became compelling questions to ponder.

Could this shift in focus towards planning for the future be the original source of mental illness? As technology and, consequently, life itself have become more complex, we find ourselves forced to make more difficult choices. We agonise over the endless permutations and possible worst-case scenarios.

On the other hand, many animals, if fortunate to survive a predatory pursuit, will appear to chomp away at their food as though nothing had ever happened. I would question whether they have thought deeply beforehand about the actual degree of pain involved in being torn apart, or who would look after the family.

From Joe Lewis, Falmouth, Cornwall, UK

I have bipolar disorder. In the modern world, that is often very unhelpful, particularly during hypomanic episodes.

However, in a hunter-gatherer society, I could see these episodes having an advantage. You could stay up all night to watch out for danger. Even the hallucinations that come with psychosis may have been seen as important to a community that believed in communicating with the spirits.

I would say the biggest downside of mental health conditions is living in a society that stigmatises you. If the society embraces your difference, then you can still be a valuable part of the community, and there is no need for evolution to remove those genes from the gene pool.

On the crime and punishment debate

18 October, p 19

From Jon Atack, Nottingham, UK

Thank you for Raihan Alam and Tage Rai's excellent article on how society punishes people. The Mendota Juvenile Treatment Center study showed that offenders who received counselling did far better than those who didn't. The science shows that kindness leads to a better outcome for all concerned.

From Dave Neale, Bedford, UK

Throughout humankind's history, we have had to get used to taking high risks simply in order to eat. If it didn't take risks, the tribe starved. Humanity has evolved to live with risks as a part of normal life. So the idea that criminals are deterred by the fairly low risk of being caught and consequently punished is essentially flawed.

From David Aldred, Brough, East Riding of Yorkshire, UK

On the main subject of untethering punishment from profit, I think the easiest way to remove any perception of authorities fining people in order to fill financial holes would be to fine them and burn the money. Then the criminal would be punished but the punisher wouldn't profit.

Ghosts and spirits in the marshes

11 October, p 15

From Jim McHardy, Clydebank, West Dunbartonshire, UK

As your article states, it is very likely that will-o'-the-wisps are caused by the ignition of methane or phosphine when bubbles of these merge.

High-speed propellers and pumps are affected by cavitation when the blades are travelling so fast that bubbles of vapour appear and collapse very rapidly. This violent bubble collapse can lead to extremely high pressures, temperatures and shock waves. This would also ignite the flammable gases produced by the decomposition of the organic material in the marsh and explain the "ghosts and spirits in marshes".

This does not, of course, imply that other apparitions are not to blame for some of the sightings, especially at Halloween!

Life in plastic is not at all fantastic

4 October, p 12

From John Healey, Semaphore, South Australia

I read with concern that research scientists have developed a stronger, tougher plastic. Why? Plastics contribute massively to greenhouse gas emissions, pollute the oceans and kill wildlife. We should be phasing out plastics, not inventing more.

Some animals do, in fact, like it hot

18 October, p 44

From Matthew Stevens, Sydney, Australia

James Wong describes the use of chilli powder to deter wildlife from eating plants in the home garden. I too thought it was a good idea when ring-tailed possums discovered my rhubarb patch. Yet they seemed to enjoy the treat even more. It seems Australian wildlife is tougher than those European wimps. I moved the patch.

The benefits of selective hearing

11 October, p 16

From Bryn Glover, Ripon, North Yorkshire, UK

The short article by Caroline Williams about the selective detection of sounds was of particular interest to me as one who depends significantly on hearing aids.

The problem is that in, say, the dining area of a pub, the aids will selectively home in on what happens to be the loudest sound at the time, so loud voices or loud laughter at nearby tables means that my own table's conversation can be quite drowned out.

If I turn off my aids, my level of hearing drops significantly, but I am then – to a small degree – able to benefit from the effect described by Williams.

Who needs to make sacrifices for the climate?

Letters, 11 October

From Albert Beale, London, UK

Vincent Flood, in Illinois, US, pins inordinate faith on geoengineering to keep our planet in a habitable state – partly, it seems, because you can't "tell people in low-income countries they can't have air conditioning or cars...". But people in low-income countries currently aren't the biggest problem. The people who do have to be forced to quickly give up most of their cars and flights are those living in the richest countries, like mine, and Vincent's.

The poisonous effects of a poor performance

11 October, p 20

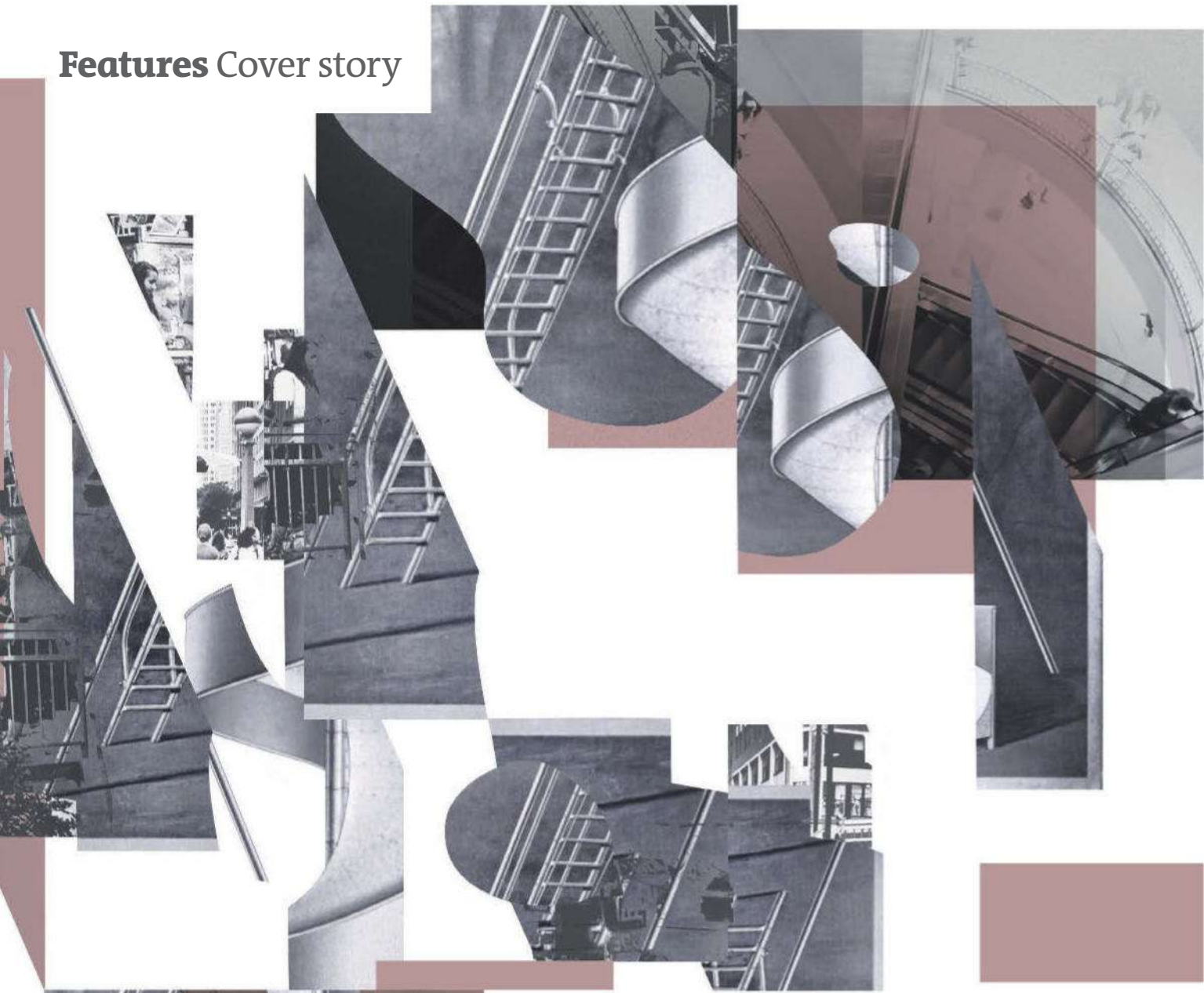
From Richard Dendy, Oxford, UK

Graham Lawton writes about the conspiracy theory that bad actors are using aircraft contrails to poison us. I have experienced the discomfort caused by ham acting in the theatre, but was surprised that bad actors could poison the upper atmosphere as well.

Want to get in touch?

Send letters to letters@newscientist.com; see terms at newscientist.com/letters

Letters sent to New Scientist, 9 Derry Street, London, W8 5HY will be delayed



No space, no time, no particles

Take quantum theory seriously and a surprising, beautiful new vision of reality opens up to us, says physicist **Vlatko Vedral**

"Some physicists think we need to tweak quantum theory – but not me"

MANY have pinpointed the birth of quantum mechanics to the small, treeless island of Helgoland, where a young Werner Heisenberg went in the summer of 1925. There, he sketched out the basics of what would become our most brilliant and successful way of explaining reality. At the heart of his approach was the decision to focus exclusively on what observers would find when they measured particles.

It was a flash of genius – but it has also tied physicists up in knots for 100 years. Much of the trouble comes down to questions about what an observer is and what exactly constitutes an observation. Are we to believe that reality is somehow contingent on us looking at it?

I believe it is now time to move on from this metaphysical mess. I have thought about quantum theory for much of my career and I have come to believe we don't need observers – it makes no sense to talk about them. There is a much more consistent and reasonable way to describe the quantum world that I would like to share with you now, together with the three clinching experiments that can prove my case.

While this framework, in my opinion, makes a lot of logical sense, it takes us into unfamiliar territory. It's not just observers that don't exist – there are no particles either. And space and time? Well, we will get to them. These are deep waters, to be sure, but it is worth wading in because, as we do so, we find clues to what might lie beyond quantum theory as we know it.

To begin with, let's take a whistle-stop tour of modern physics and the spider's web of problems it creates. Observers were a key tenet of physics long before quantum mechanics: indeed, they played a crucial role in Albert Einstein's development of both special and general relativity. The latter theory says that space and time are melded together in the fabric of space-time, and it is the bending of this fabric that creates gravity. I will challenge this view later, but one implication of the original idea is that observers in places where the curvature of space-time is different will experience time passing at different relative speeds.

When we teach relativity, we often talk about observers in this way, imagining them as people. But the truth is that the time experienced by any moving object (even, say, an atom) will change with respect to objects in differing gravitational fields. These differences needn't be recorded by observation, so we don't need a special category of "observers".

General relativity is the first of the two pillars of modern physics, the other being quantum theory itself. The essence of the theory is that reality is divided into discrete chunks at the most fundamental level. For example, when atoms take in or spit out energy, it happens in packets of a certain size, not continuously. But observers are baked into quantum theory too, because it distinguishes between particles before and after "observation". Beforehand, we describe them using the wave function, an equation that sets out a range of possible properties – a superposition. Afterwards, this is said to "collapse" into a specific value.

The trouble is, this gives rise to all sorts of questions, the most basic of which is how and why collapse happens. It also creates paradoxes, such as Wigner's friend, dreamed up decades ago by physicist Eugene Wigner. He imagined a "friend" inside a sealed lab making a quantum measurement while he himself waited outside. The problem comes when we compare the two people's descriptions of reality. Wigner hasn't observed anything, so the whole lab is described by the fuzzy wave function. Yet, for his friend, there is a definite outcome. With this paradox, Wigner was asking how we know when an observation becomes definitive.

Some physicists think we need to tweak quantum theory to deal with all this. But not me. To explain how I think about it, we need to grasp the phenomenon of entanglement, which Erwin Schrödinger called quantum theory's "characteristic trait". Quantum ›

SKIZZOMAT

TITIPONG MAKKARACHGETTY IMAGES

We often talk of "observers" in physics, but this may be misleading

entanglement is often seen as mysterious, but it is really just a special link between two quantum objects such that when you measure one, you immediately know something about the other's properties. Here's the key point: when we talk about "observations", what we are really referring to, in my opinion, is the moment two systems become entangled with each other. Although the thing that gets entangled can be a person – an "observer" – it doesn't have to be.

Let me give you an example. There is a famous experiment in which a particle of light, or photon, in superposition goes through two slits in a screen at the same time, creating an interference pattern when it hits a second screen. But if we observe which slit the photon goes through, then no interference takes place. Before you conclude that our observation collapses the superposition, bear in mind that if we entangle anything else with the photon in a way that reveals which slit it takes, we get the same effect.

So we should stop talking about "observers" and instead talk about entanglement. By the way, this view dissolves the question Wigner raised with his paradox, too. There is no "ultimate" observer – there are no observers at all. What really happens is that the system and observer (just another system) become entangled.

What I would like you to take from all this is that quantum theory already contains everything we require to understand reality. We only need to take its full implications seriously – even if they appear strange. So, let us now explore where that takes us, starting with a central idea in physics: particles.

To grapple with this concept, the first things we need to deal with are fields. A field is an entity that exists everywhere and changes over time, an idea originally introduced by Michael Faraday in the first half of the 19th century. In classical electromagnetic field theory, the electric and magnetic field values are ordinary (or classical) numbers called c-numbers, as in 5 metres. Each point in space has three electric field numbers and three magnetic field numbers assigned to it.

In quantum theory, we instead talk about quantum fields where every point in space is described not by single numbers, but instead tables of numbers. These tables are called quantum numbers or q-numbers. This is why many people take Heisenberg's 1925 paper as the beginning of quantum physics: he was the first to propose upgrading the positions and momenta of particles to q-numbers. This difference between c-numbers and q-numbers is simple but profound – we will come back to it later.

However, not everyone is prepared to take seriously the full implications of quantum fields. When physicists took the classical electromagnetic field and quantised it, this implied the field could oscillate in more modes than was previously possible. In the quantum field, there are four of these modes and the theory predicts that the field should be able to manifest as particles, in this case photons, in each one. But here's the weird thing: we can only ever detect photons in

"We have been misled into thinking particles are fundamental"

"I take the radical view that space and time don't exist at all"

two of these modes. The other two cancel out and aren't detectable, even in principle. These "ghost" photons are therefore unobservable yet unavoidable.

Philosophically troubling? Perhaps. But this isn't unusual. Much of science works this way. We postulate things because the explanatory power of a theory would fall apart without them.

Ghost hunting

I don't think we should sweep these oddities under the table, but should embrace them. Chiara Marletto, my colleague at the University of Oxford, and I have suggested that even though these ghosts can't be directly detected, they should get entangled with electrons under certain circumstances and this entanglement could, in principle, be detected. As we set out in a 2023 paper, you could do this by putting an electron into a superposition, whereupon, if we are right, it should get entangled with the ghosts, and this would be detectable with the right kind of careful measurement. It is a challenging experiment, but certainly one that lies within the reach of existing technology. It would be a quantum equivalent of seeing a ghost.

What would it mean if this experiment showed that these ghosts can be entangled, as I fully expect it would? The most basic thing we normally think of as capable of being entangled is a particle. But ghosts can't truly be considered particles. All they are, in truth, is q-numbers in an equation. But that, for me, is precisely the point. It is the q-numbers that are fundamental, not the human conception of a "particle". It just so happens that particles have q-numbers, and that has misled us into thinking the former are the fundamental elements of reality, when it is actually the latter.

There is another layer of sophistication that reinforces my argument that particles aren't real. Let's consider an individual particle, say an electron. In the language of vanilla quantum theory, we would say that, before we measure this particle, it is in a superposition of states. It is both here and there, and both possibilities are described by q-numbers. But now change your perspective. If q-numbers are the essence of reality, these two q-numbers can be entangled with each other. Put another way, you might say that a particle in superposition can be "entangled with itself".

Not all physicists would accept this is possible, but more than 15 years ago, I proposed an experiment that can determine the truth, this time with my colleague Jacob Dunningham, now at the University of Sussex, UK. Take a single particle and make its state delocalised, so that it is in a superposition of two different physical locations. To experimentally verify whether the superposition is entangled, you need to make separate measurements in the two different locations and check if they violate an equation called Bell's inequality, the hallmark of entanglement.

There is already some evidence that this single-particle entanglement occurs. Experiments conducted by Björn Hessmo at the KTH Royal Institute of Technology in Sweden and his colleagues in 2004 showed that individual photons split between two positions do violate Bell's inequality. Photons, in other words, aren't fundamental elements of reality – it is their q-numbers that matter. Still, photons are massless and no one has yet done this with an object with mass, such as an atom or even a much lighter electron, because those experiments are challenging. But there is no doubt in my mind that the outcome would be the same.

SUNNY TIWARI

Vlatko Vedral working on an entanglement experiment

Now we are ready to talk about space and time. Some people think of this as the last frontier of physics, and it is related to the field's biggest open problem, namely that of combining those two pillars of physics, general relativity and quantum theory, into a theory of quantum gravity. Since I have so far argued that we should think of everything as being made up of q-numbers, you might anticipate that space and time should be quantum too. Indeed, many researchers think this.

But here I take a more radical view: space and time don't exist at all. Like "observers", they are convenient labels – bookkeeping devices – but there are no physical entities corresponding to them. Therefore, quantising gravity doesn't mean quantising space-time, it means quantising the gravitational field (upgrading Einstein's c-numbers into q-numbers) in the same way that other fields are quantised.

This might seem a subtle point. After all, in general relativity, the gravitational field is thought of as being nothing more and nothing less than bending space-time. But this is where I put a twist on things: what bends isn't space or time, but fields like the electromagnetic field that holds all matter together. Atoms, molecules, clocks and rulers are all bound by electromagnetism. The job of the gravitational field is to couple to these fields and tell them how to bend. For convenience, we talk about these fields being laid across an invisible grid we call space-time. That's fine, but let's not fool ourselves into thinking space-time is fundamental.

Some of my colleagues may consider this pretty extreme, and I admit it is hard to think of any experiment at present that could prove I am right. But for me, this is all part of ›

New Scientist audio
You can listen to many articles – look for the headphones icon in our app **newscientist.com/app**

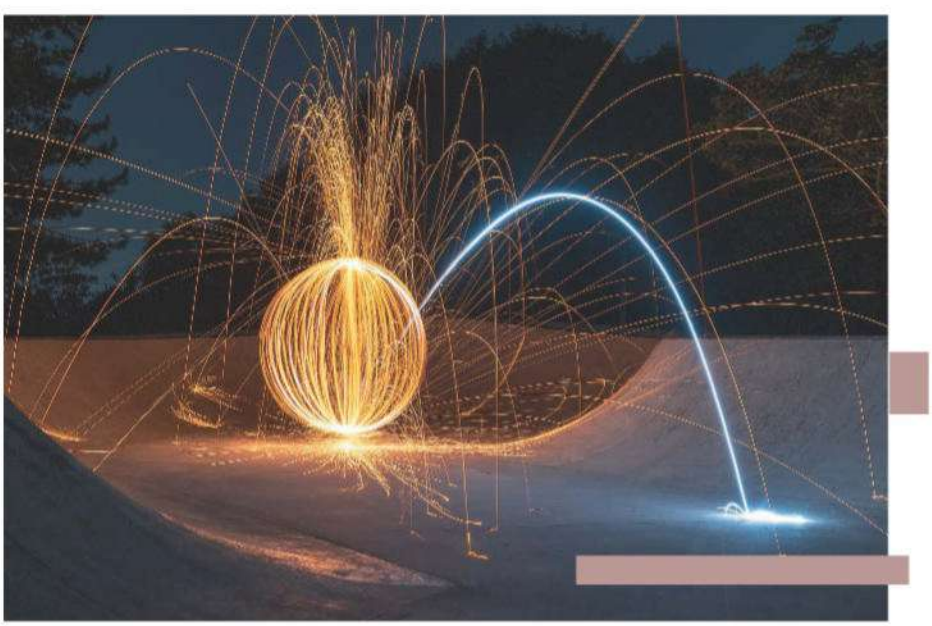
taking quantum theory at face value. I am suggesting that gravity should be just like any other quantum field.

So: no particles, no space, no time. Instead, I think the basic ingredient of nature is the q-number. To finish, let's explore how fully embracing this principle might lead us towards new insights. What I am about to say brings to mind the story of when philosopher Bertrand Russell had a cosmology lecture interrupted by an attendee who claimed that the universe is carried on the back of a gigantic cosmic turtle. When Russell asked her what the turtle stands on, she replied: "It's turtles all the way down!" My proposal is similar, although no turtles are involved.

Particles may not be a fundamental part of reality

When we talk about how quantum fields interact, we use a piece of mathematics called the quantum Hamiltonian. It has long bothered me that these Hamiltonians mix q-numbers with ordinary c-numbers – for example, physical constants such as the speed of light or the electron charge. This is routine, but it doesn't seem right to me. Over the past century or so, physicists took classical equations and made some bits of them quantum. But wouldn't it be neater, and in the spirit of the philosophy I have been espousing, if our equations were quantum through and through?

I'm not the first to think like this. In the 1980s, physicist David Deutsch proposed eliminating c-numbers altogether, making all the quantities in quantum Hamiltonians into q-numbers. Doing this, however, would have strange consequences. Let's take just one of the possibilities and look at the speed of light, which we currently treat as a simple c-number. If we turned this into a q-number – which, remember, always describes a point in a quantum field – this would imply that there is some new quantum field connected to the speed of light. It would be a bit like what happened when we quantised the electromagnetic field and got those pesky ghosts – a suggestion that there is more to reality than we thought.



PETE GODFREY/UNSPLASH

"There could be some new quantum field connected to the speed of light"

Turtles all the way down

This general idea can be subjected to experiment. If there are extra quantum fields out there, particles should be capable of becoming entangled with them. Imagine, for example, you maximally entangle an atom and a photon. If there is another field out there that mediates this interaction, it should join the party and create a three-body entangled system. The result would be that the strength of the entanglement between the photon and the atom would be weaker than expected. In 2022, Jim Franson at the University of Maryland, Baltimore County, proposed one method for detecting this entanglement – it is conceptually quite similar to the experiment I imagined for detecting the ghosts. No one has performed this so far, but it is technologically possible.

In principle, we could imagine taking quantisation to an even deeper level. Q-numbers are tables of numbers, and you could easily "upgrade" all of the ordinary numbers in those tables to be q-numbers themselves – and then do the same again. Tables of tables of tables. In this view, it isn't turtles, but rather q-numbers, all the way down.

Philosophers hate infinite regress. But nature is under no obligation to respect our philosophical scruples. The universe may simply be a bottomless pit, offering physicists an inexhaustible supply of mysteries. ▮

Vlatko Vedral is a physicist at the University of Oxford. His book *Portals to a New Reality* is out now

Take your daily **multivitamin** to the **next level**.

All your daily essentials – plus scientifically proven support for your gut, energy, immunity and cellular health

Total body support – 23 vitamins, minerals and nutrients, chosen to support UK diets, in highly absorbable forms

Gut-friendly bacteria – from LactoSpore®, supported by multiple clinical studies

Fights oxidative stress – with vitamin C plus AstaPure® astaxanthin

Energy support – with B vitamins and bioavailable CoQ10 from Ubiqsome®

Scientifically proven ingredients – including MenaQ7® vitamin K2, slow-release PureSea® iodine, ready-to-use Quatrefolic® folate and more

FutureYou
CAMBRIDGE
Advanced Multi+
Daily multinutrient formulation with Affron®, AstaPure®, UbiqSome® & LactoSpore®
23 carefully selected vitamins, minerals and nutrients to build your long-term wellbeing and keep you nourished, energised and resilient.
Food supplement
56 vegan capsules

'Advanced Multi+ is an easy, effective way to support your health every day – whether you're navigating a busy lifestyle, managing changing needs with age, or simply building a stronger foundation for your future.'
– Dr Miriam Ferrer, PhD, Head of Product Development at FutureYou Cambridge

Try Advanced Multi+ for just £10

Your first box is just £10, with free delivery included. After that, subscription boxes cost £28 and arrive every 28 days. You're always in control – **amend, pause or cancel anytime, with no obligation.**

Order today at **futureyouhealth.com** with code **ADX109**

Or call our award-winning customer care team on **0800 808 5740**

Try it now

with code ADX109

Introductory offer valid for new UK customers only. RRP: £28. Offer expires 31st December 2025 and cannot be used in conjunction with any other promotions. Cancel any time, without obligation. See futureyouhealth.com/ADX109 for full terms and conditions.

Contains

Magnesium contributes to normal energy-yielding metabolism.

Vitamins C and D contribute to the normal function of the immune system.

B2 contributes to the maintenance of normal mucous membranes.

Trustpilot ★★★★★
Rated EXCELLENT with over 15,000 reviews

Backed by science, trusted by thousands
Developed in Cambridge, UK.

FutureYou CAMBRIDGE

Ancient plagues

A surge in contagious diseases in Europe 5000 years ago helped shape humanity, finds **Laura Spinney**

DISEASE historians have a problem. While examining samples of ancient human DNA, geneticists have come across genes belonging to the plague bacterium, *Yersinia pestis*, revealing that it ravaged Eurasia 5000 years ago. That's nearly 3500 years before the "first plague", also known as the Justinian plague, after the Roman emperor of the day. What to call this newly discovered prequel?

The current favourite, the Late Neolithic-Bronze Age (LNBA) plague, is a bit of a mouthful. But the scientists have more to worry about. Their chance discovery is another nail in the coffin of a long-held idea about when and why humanity acquired many of the contagious diseases that now afflict us. Of late, they have uncovered a rogue's gallery of prehistoric horrors in samples taken from ancient humans. These so-called zoonotic diseases bothered animals before they bothered people, so were thought to have jumped the species barrier after humans invented agriculture, around 12,000 years ago. But as geneticists can peer further back into the past, they are finding that in many cases the leap occurred much later – with major outbreaks happening in Europe, you've guessed it, around 5000 years ago.

As well as upending old ideas about disease evolution, the discovery has forced a rethink of a pivotal period in prehistory. How were diseases spreading at that time? Did the pathogens have the same effects as they do now? And might plague itself have ushered in the Bronze Age, laying the foundations of European civilisation? It's exciting stuff, says archaeogeneticist Megan Michel at Harvard University, given that a decade ago, "we didn't even know this plague existed".

The reconstruction of ancient disease landscapes has been a huge collaborative effort, but a group at the University of Copenhagen in Denmark has had a leading role. They began routinely screening ancient human remains for known pathogens about 15 years ago, having unexpectedly found microbial DNA in human samples. Armed with radiocarbon dates and information about how people in prehistoric cemeteries were related to each other, they could start to build a picture of the cultural and economic context in which the diseases spread. They could also track the evolution of pathogens over time – and investigate how the human immune system adapted in turn.

This approach has generated a quickfire sequence of important findings, including the discovery of pathogens that cause typhoid, hepatitis B, syphilis and smallpox in historical human populations – and culminated this July in the publication of a study led by population geneticist Martin Sikora, a member of the Copenhagen group. His team re-analysed around 1300 human samples spanning more than 35,000 years in Eurasia. All the DNA came from teeth, which preserve blood-borne pathogens because they have their own blood supply in life. Among the pathogens the researchers found were *Y. pestis* and the bacteria that cause leprosy and leptospirosis, or Weil's disease. To their surprise, nearly 3 per cent of samples tested positive for another pathogen, *Borrelia recurrentis*, the causative agent of the now-rare relapsing fever – a relative of Lyme disease characterised, as its name would suggest, by recurring fever and blinding headaches.

SIMON PEMBERTON

The team also looked at trends over time. These revealed that until about 6500 years ago, the vast majority of microbes in the teeth of Eurasians belonged to the oral microbiome – the diverse, usually harmless or even beneficial community of organisms that inhabits the mouth. The first zoonotic pathogens, including plague, became detectable at that date, but only at very low levels. It wasn't until around 5000 years ago that there was a spike in infections from *Y. pestis* and other major pathogens.

This also happens to be the date that nomadic herders called the Yamnaya began arriving in Europe from the steppe, a vast expanse of grasslands and savannas spread across much of Eurasia, bringing new ideas and new languages. Coincidence? The researchers think not. Those herders had an exceptionally high burden of infectious disease. It isn't clear why, but it was probably linked to their lifestyle. They kept much larger herds than static farmers – of sheep, goats, horses and cattle – and they lived with their animals around the clock. Their diet consisted mainly of meat and milk. "A lot of zoonoses can be transmitted through undercooked meat, but also through milk: brucellosis, listeriosis, bovine tuberculosis, to name just a few," says infectious disease expert Astrid Iversen at the University of Oxford.

"Infectious disease is the loudest silence in the archaeological record"

Other findings appear to corroborate this hunch. For instance, by tracing how the genome of plague bacteria changed over time, archaeogeneticist Pooja Swali at University College London has been able to show that ›

4000-year-old cases of plague – which were the oldest known in Britain when she documented them in 2023 – were caused by strains related to those carried earlier out of the steppe. She could effectively see the disease moving from east to west.

Then there is relapsing fever. Earlier this year, Swali reported that *B. recurrentis* became specialised to humans in a window centring on 5000 years ago. Before that, the bacterium infected a range of mammals via the tick, its intermediate host, but then it swapped this out for the human body louse. Swali speculates this had to do with wool clothing, another innovation – besides metal tools – brought to Europe by the steppe nomads. At that time, *B. recurrentis* underwent a major reduction of its genome, which could reflect adaptation to a new host – one that flourished in wool. "Maybe this massive reduction in genome meant that it became trapped in lice," she says.

Meanwhile, French researchers have shown that the immune system of Europeans began adapting to infectious diseases like these around 6000 years ago, with the bulk of immunity-related genetic variants appearing around 4500 years ago. "All these pieces fit really nicely together," says Sikora.

But there's one piece that doesn't fit so well. Sikora's July paper cites two cases of plague in Orkney, off the north coast of Scotland, that predate the arrival of people with steppe ancestry in Britain by at least 500 years. What's more, last year, another member of the Copenhagen group, Frederik Seersholm, described three outbreaks of plague over six generations of Neolithic Swedish farmers that occurred around 5000 years ago. Those farmers carried no steppe ancestry, indicating they had yet to interbreed with – perhaps even to meet – these populations of eastern origin. A new study from Seersholm and Ruairidh Macleod at UCL, which has yet to be peer-reviewed, describes the oldest instances of plague in the world recorded to date, from around 3500 BC, which proved fatal to hunter-gatherers living near Siberia's Lake Baikal, east of the Yamnaya's point of departure westward.

Such cases have persuaded most people that plague was geographically widespread before the nomads arrived. One idea is that the LNBA plague got its foothold in the mega-settlements of the Trypillia culture of present-day Ukraine, beginning around 6000 years ago, and then spread through trade networks. Archaeogeneticist Nicolás Rascovan at the Pasteur Institute in Paris, who suggested this possibility in 2019, says his hypothesis remains on the table, though he admits it is difficult to test because almost no Trypillian burials have been found. Others are sceptical. A team led by anthropologist Alex Bentley at the University of Tennessee, Knoxville, has shown that the clustered layout of Trypillian megasites could have introduced effective firebreaks to contagion. Besides, the Baikal cases indicate plague was a problem for hunter-gatherers from an early date.

Plague without fleas

What the disease was like back then is also unclear, but there is no doubt it could kill. "Whether it was as highly transmissible as the Black Death, I'd be more cautious," says Sikora. It is unethical to try to revive ancient plague strains in the lab, but you can get a rough idea by comparing ancient plague genomes with later strains that have known clinical outcomes. Such analysis has revealed that LNBA strains lacked a genetic variant that allowed the bacterium to survive in the flea gut, leading researchers to conclude that they probably weren't transmitted by flea bites, as the Black Death was in the 14th century.

There are many other ways plague could have spread in the Late Neolithic, though. Macleod and Seersholm suggest it was airborne and spread through coughing. But we can't assume it was capable of human-to-human transmission. Another possibility is that outbreaks were caused by people sharing feasts of undercooked, infected meat – in which case, each outbreak was an animal-to-human spillover event that probably fizzled out quickly. Plague has many animal reservoirs, including sheep, dogs and rodents, and researchers know very little about how prevalent it was in other species in the Late Neolithic, or how it evolved in them. "What's missing is this huge piece of the puzzle – the animals," says Swali.

Amid all the uncertainty, arguably the most burning question is whether the plague caused the so-called Neolithic decline, a dramatic fall in the population of western Eurasia. If so, it might also have ushered in the Bronze Age in that part of the world, a cultural revolution that introduced a more hierarchical and warlike social model – perhaps by clearing the way for those nomadic steppe herders who organised themselves in that way.

SCIENCE HISTORY IMAGES/ALAMY

Plague doctors treated victims of bubonic plague during outbreaks in Europe

PIOTR WŁODARCZAK, NATIONAL SCIENCE CENTRE (KRAKÓW, POLAND) TITLED "FROM THE STEPPES TO THE BALKANS: YAMNA CULTURE IN THRACE"

Yamnaya nomads (left) moved across Europe as diseases carried by animals like lice (below) spread

MARTIN OEGGERLI/SCIENCE PHOTO LIBRARY

Neolithic farmers lived in denser, more permanent settlements than herders or hunter-gatherers, and lots of people living in proximity certainly lend themselves to contagion. Seersholm thinks his study of Swedish farmers supports the idea that plague caused their decline. However, archaeological evidence – the thinning of the farmers' cultural footprint, signs of violence and the regrowth of forests – suggests it began around 7000 years ago, 500 years before the first zoonoses appeared in Europe. "I retain my scepticism that plague is responsible for this population downturn," says archaeologist Stephen Shennan at UCL. He thinks the root cause was an agricultural crisis – shrinking crop yields related to a cooling climate. Nevertheless, he says he might have to change his mind if earlier plague cases come to light.

That is possible. Geneticists are confident the prehistoric prevalence of infectious disease was much higher than is detectable, in part because a disease can kill without showing up in the patient's blood. This is the case for tuberculosis, for example, but also for the pneumonic form of plague, which infects the lungs. RNA viruses such as coronaviruses and flu aren't yet detectable, either. Researchers are searching for more evidence that Neolithic communities cratered as a direct consequence of plague. And one of them, archaeologist Kristian Kristiansen at the University of Copenhagen, thinks they will find it.

Whether or not the LNBA plague caused the decline, it could have exacerbated it – especially after the arrival of the Yamnaya. Kristiansen doubts that their expansion into Europe was driven by plague – he prefers the theory that population growth forced them to go in search of new pastures. But, he says, they might have picked up plague en route, to which their lifestyle offered them at least partial immunity, and then spread those strains far and wide. Their contact networks extended much further than those of farmers. "You can see it clearly in the human DNA," says bioarchaeologist Thomas Booth at London's Francis Crick Institute. "Suddenly, after 3000 BC, there are biological ties stretching right across Eurasia where previously they had been more confined to smaller regional clusters."

Shaping evolution

And, of course, plague wasn't the only disease to have a major impact. "One of the big takeaways for me, from the Sikora paper, is that around 10 per cent of the tested remains had positive evidence for a major infection at time of death," says one co-author, evolutionary biologist Evan Irving-Pease at the University of Copenhagen. "The level of evolutionary pressure that would have exerted on ancient human populations is really quite substantial." He and others believe that, in today's more hygienic environment, variants of genes that were selected because they protected our ancestors from zoonotic disease predispose us to a different threat – autoimmune diseases such as multiple sclerosis (MS).

Last year, with William Barrie at the University of Cambridge and others, Irving-Pease reported that a major genetic risk factor for MS tracks with steppe ancestry in Europe, being highest in the north of the region and lowest in the south. MS can be triggered by infection with the common Epstein-Barr virus today, but a different dangerous pathogen, prevalent in the Bronze Age, might initially have driven selection for that risk factor. Irving-Pease doesn't know what it was, but with Iversen and others, he is hot on its trail.

And the Late Neolithic disease surge may have shaped more than the immune system. Before then, Europeans didn't practise dairying and were mostly lactose intolerant – unable to digest the sugar in milk. One surprising discovery is that the Yamnaya were, too: they probably consumed milk in fermented form – as yoghurt, kefir or cheese – and unwittingly recruited free-living bacteria to digest the lactose for them. So they didn't bring Europeans the genes that allow us to do this. Instead, research hints, these variants may have increased in frequency when bouts of disease and associated famines forced Neolithic farmers to drink milk to survive.

Disentangling these complex biological and cultural interactions has implications for the future. Researchers may be close to uncovering the origins of MS, for example, but they can't yet explain why it is becoming more prevalent over time. And zoonoses continue to pose a threat, accounting for an estimated three-quarters of emerging human diseases, including covid-19 – often because of our industrial-scale farming practices, destruction of forests and alteration of the climate. Understanding how they shaped us in the past will help us predict what lies ahead – and, potentially, to intervene with the powerful tools of modern medicine.

For the moment, though, it is the prospect of shedding light on our past that excites researchers most. "We can start to ask more interesting questions about the role of pathogens in human prehistory," says Michel. Infectious disease has been called "the loudest silence in the archaeological record". Finally, we are dialing up the volume. ▮

"What's missing is this huge piece of the puzzle – the animals"

Laura Spinney is a a writer and science journalist based in Paris

"You have to specifically outlaw addictive systems"

Tim Berners-Lee invented the world wide web with a utopian idea in mind. In a time of problematic social media use, polarisation and fears around AI, he tells Timothy Revell the plan for bringing it closer to his original vision

TIM BERNERS-LEE has a map of everything on the internet. It can fit on a single page and consists of around 100 blocks connected by dozens of arrows. There are blocks for things like blogs, podcasts and group messages, but also more abstract concepts like creativity, collaboration and clickbait. It plots the lay of the digital landscape from a unique vantage point: the view of the man who invented the World Wide Web.

"Most of it is good," he tells me, sitting in *New Scientist*'s London offices, as we discuss what has gone wrong and what has gone right with the web. He created the map to help show others – and perhaps also remind himself – that the parts of the internet judged as causing harm to society form only a small fraction of it. The top left quadrant makes it clear where Berners-Lee thinks the problem lies. Six blocks earn the label "harmful". Written inside are the words: Facebook, Instagram, Snapchat, TikTok, X and YouTube. Over the past 35 years or so, Berners-Lee has watched his invention go from a single user (himself) to 5.5 billion – about 70 per cent of the world's population. It has revolutionised everything from how we communicate to how we shop. Modern life is unimaginable without it. But it also has a growing list of problems.

Misinformation, polarisation, election manipulation and problematic social media use have all become synonymous with the web. It is a far cry from the collaborative utopia Berners-Lee envisioned. As he writes in his new memoir, *This Is For Everyone*, "In the early days of the web, delight and surprise were everywhere, but today online life is as likely to induce anxiety as joy."

It would be totally understandable if the web's inventor were a bit sour about what humanity has done with his life's work, but he is far from it. In fact, Berners-Lee is extraordinarily optimistic about the future, and the future of the web. As one of the most influential technological thinkers of our time (with a long list of awards and a knighthood to prove it), he has plenty to say about what's gone wrong – and most importantly, how he hopes to fix it.

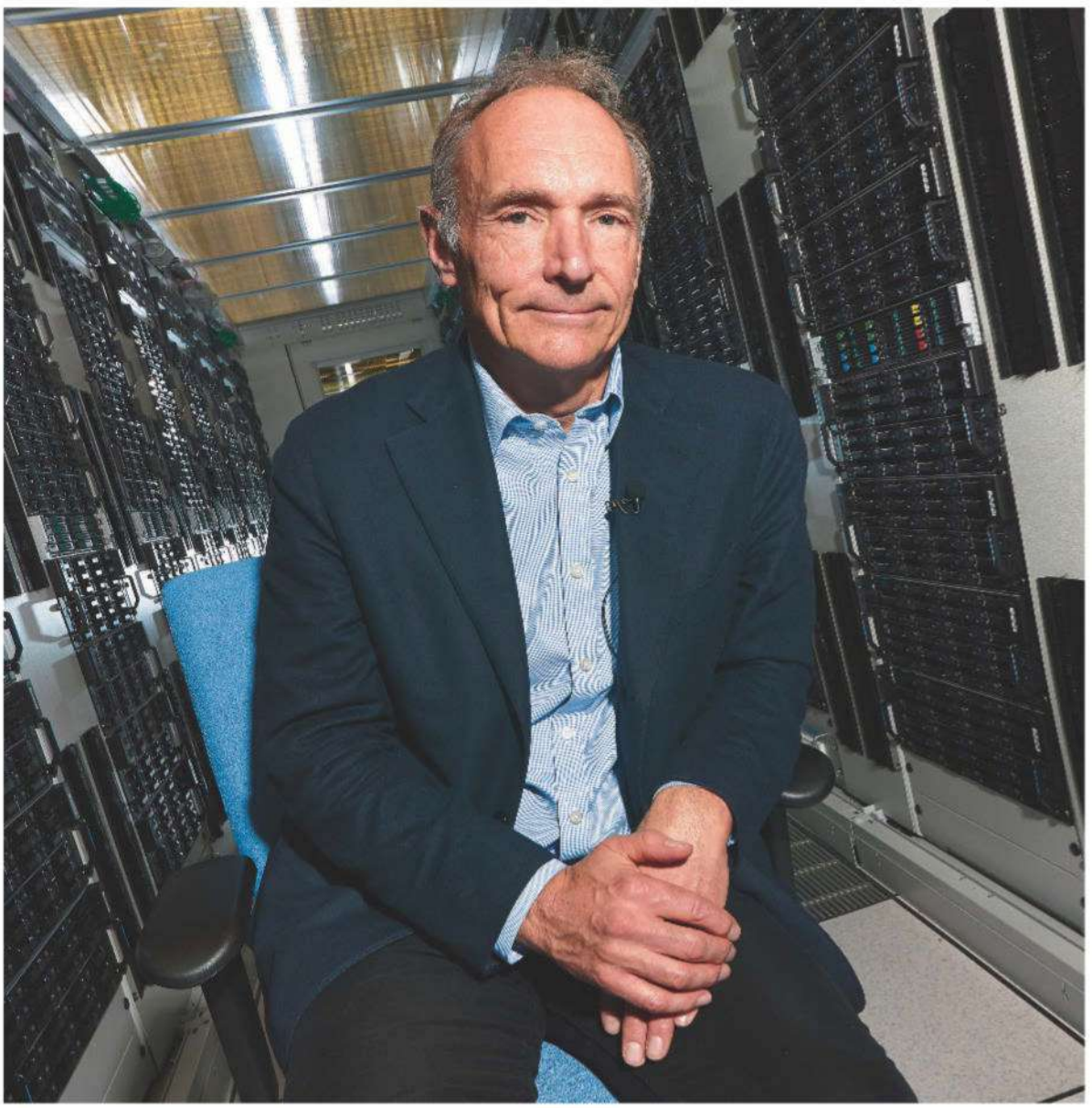
Inventing the web

The origin story of the World Wide Web is partly about being in the right place at the right time. In the late 1980s, Berners-Lee was working in the Computing and Networks division at CERN, the particle physics lab near Geneva, Switzerland, and he was wondering whether there was a better way to manage all the documentation. Most systems forced users to follow particular rules for how documents should be organised, imposing strict hierarchies and relationships. Berners-Lee thought it would be better to let people connect documents in any way they liked. Hyperlinks already existed for linking things together within documents, and the internet already existed as a way to share files, so why not put the two together? This simple yet groundbreaking idea became the World Wide Web.

The idea existed for some time in Berners-Lee's head before, in 1989, he eventually convinced a sympathetic boss to let him pursue it full-time. In a matter of months, he produced a burst of acronymic activity that spawned HTML, a programming language for building web pages; HTTP, a protocol for sending them; and URLs, a way to locate them. Just 9555 lines of code in total. By the time the year was out, the web was born.

"CERN was a really great place to invent the web," he says. "It has people from all over the world who have this desperate need to communicate and to document their lives and their systems."

The first website, which was hosted on ›



BRICE, MAXIMILIEN/CERN

Berners-Lee's work computer with a do-not-turn-off sign stuck to the front, outlined what the web was and how to join in. A few web servers sprang up, then a few more. "It went up by a factor of 10 in the first year, and then it went up by a factor of 10 the second year. And then in the third year [it] went up by a factor of 10 again," he says. "Even back then, you could see that we were onto something. You had to buckle up and hold on."

Most of the early web pages were made by academics and software developers, but people soon started to use them to put everything and anything on the internet. Within a decade, there were millions of websites, hundreds of millions of users and enough internet companies to fill a dot-com stock market bubble. Despite the huge money-spinning opportunities of the web, Berners-Lee felt that for it to reach its true potential, it needed to be free and open. But that was easier said than done. As he had developed the software underpinning the web while at CERN, the organisation had a legitimate claim to charge royalties to anyone who used it. Berners-Lee turned to his superiors and pleaded the case that the technology should be donated to the world. It took a while to find someone who could actually sign off on such a thing, but in 1993, the full source code of the web was published along with the disclaimer, "CERN relinquishes all intellectual property rights to this code." The web would be royalty-free forever.

For the first few decades of its life, the web seemed to be going pretty well. Yes, there was the infamous turn-of-the-millennium stock market crash, though this was arguably the fault of venture capital speculation rather than the web, per se. Pirating was certainly on the rise and malware seemed to be just one bad click away, but it was largely free, open and fun. "People loved the web so much. They were just delighted," writes Berners-Lee in his memoir.

Capturing the mood of the time, he believed that the web could unlock a completely new form of human collaboration. He coined the term "intercreativity" to describe a group, rather than an individual, becoming a creative entity. Wikipedia, with its nearly 65 million English-language pages written and edited by 15 million people, epitomises what he had in mind. The site takes pride of place in his map and he describes it as "probably the best single example" of what he wanted the web to be.

Of course, this age of unfettered web optimism didn't last forever. For Berners-Lee, it was 2016 when he began to feel like something was fundamentally wrong. "There was the Brexit election and the first Trump election," he says. "At that point, people started to say it is possible that people have been manipulated using social media into voting for something that is not in their best interest. In other words, the web was part of a powerful manipulation of individuals by large organisations."

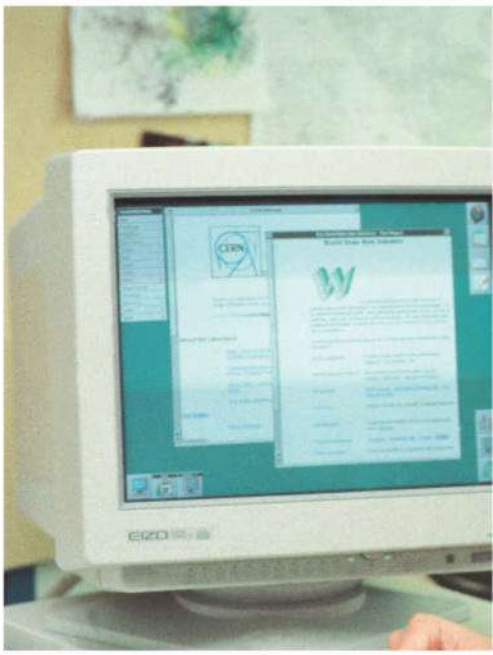
Political problems

Historically, political campaigns would "broadcast" their messages to voters out in the open, where everything could be seen – and, crucially, criticised. However, by the mid-2010s, social media had made it possible to "narrowcast", as Berners-Lee puts it. Political messages could be turned into a thousand variations, each targeted at a different group. Keeping track of who was saying what and to whom became much harder. So too did countering misleading claims.

How much this kind of microtargeting affects elections is still up for debate. Many studies have attempted to quantify how people's views and voting intentions change when they see such messages, but the studies have generally found only small effects. Either way, it plays into a bigger concern that Berners-Lee has around social media.

One of the first internet cafes in Edinburgh, in 1997

IMAGE SCOTLAND/ALAMY



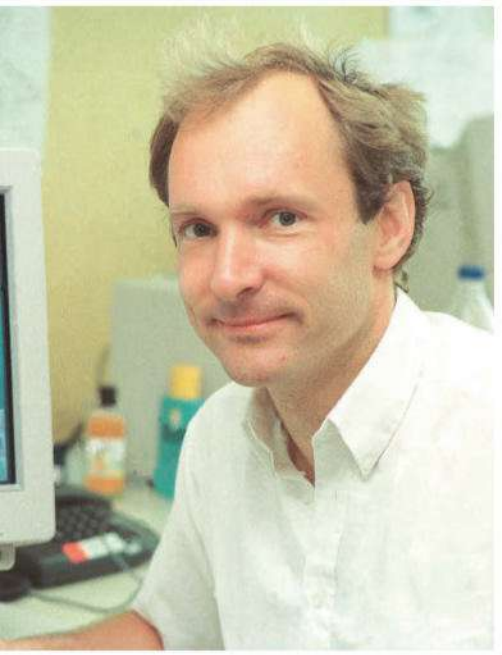
CERN

He says social media companies have an incentive to keep your attention, which drives them to build "addictive" algorithms. "It's human nature to be attracted by things that make you angry," he says. "If social media feeds you something which is untrue, you're more likely to click on it. You're more likely to stay on the platform."

He cites author Yuval Noah Harari, who has argued that people who make "bad" algorithms should be held accountable for their recommendations. "You have to specifically outlaw addictive systems," says Berners-Lee. However, he recognises that a ban isn't exactly in line with his usual free-and-open approach. It is a choice of last resort. Social media can connect people and spread ideas, but it also has a particular problem in causing harm, he writes in the new book: "We need to change that, one way or another."

Still, he remains positive about where the web could be heading. Social media is just a small part of the internet map – even if it does draw a lot of our attention. Fixing it should be part of efforts to improve the web at large, and key to that is reclaiming digital sovereignty, he says.

To that end, for the past decade, Berners-Lee has been working towards a new approach that hands the initiative back to individuals. Currently, different internet platforms control your data. You can't easily post a Snapchat video you have made to your Facebook feed or a LinkedIn post to your Instagram account, for example. You have created those posts,



"It's human nature to be attracted by things that make you angry"

but the respective companies own them.

Berners-Lee's idea is that, rather than being spread between different platforms and companies, your data would sit in a single data wallet that you control, called a pod (short for "personal online data store"). Everything from family photos to medical records could live there, and it is up to you to decide if you want to share any of it. This isn't just theoretical; he has co-founded a company, called Inrupt, to try to make this approach a reality.

He is particularly excited about the potential for data wallets to combine with artificial intelligence. He gives the example of trying to buy a pair of running shoes. If you used any of the current AI chatbots, you would have to spend time explaining what you were looking for before they could make a decent recommendation. But if an AI had access to your data wallet, it would already know all your measurements and your entire workout history – and perhaps your spending history, too – so it could precisely match your profile with the right shoe.

The AI should work for you, not big tech, says Berners-Lee. This isn't about building your own AI, but about having guarantees baked into the software. Data wallets are one part of that, although he also says that AIs should be signed up to a sort of digital Hippocratic oath to do no harm. It should be like "your own personal assistant", he says.

A better running shoe recommendation isn't exactly earth-shattering and is unlikely to fix many of the internet's sharpest problems, but Berners-Lee's greatest talent isn't to imagine exactly how people will use something, but to see the potential of it before others can. Data wallets seem dry and esoteric now, but so too did a hyperlink-based document-management system just a few decades ago. Berners-Lee says he is driven by a desire to build a better world. An improved data ecosystem is the best way he sees to do that.

This all hints at what he thinks is next for the web. He wants to see us move away from an "attention economy", where everything is vying for our clicks, to an "intention economy", where we indicate what we want to do and then companies and AIs vie to help us do it. "It's more empowering for the individual," he says.

Such a change would dramatically shift power away from the big tech companies and back to users. Given that the internet has been moving in only the other direction of late, only a particular kind of optimist could believe that a reversal is just around the corner. The hold of big tech on our lives and the era of doomscrolling seem unlikely to end anytime soon. But then again, Berners-Lee has a track record of seeing things others can't – and he is the one holding the map, after all. ▮

Above: Berners-Lee in 1994, with an early form of the websites and web browsers that he invented at CERN

Below: Social media companies including Facebook have drawn public backlash over their privacy policies

facebook
Facebook ABUSES USERS
FTC, INVESTIGATE!
FACEBOOK PRIVACY SETTINGS SHOULD BE EASY 'CAUSE CORPORATE USE OF PRIVATE INFO IS DOWNRIGHT CHEESY

JUSTIN SULLIVAN/GETTY IMAGES

Timothy Revell is executive editor of *New Scientist*

Dear David

Stand up for yourself

A reader feels overlooked and under-appreciated. **David Robson** explains why assertiveness is a keystone of good mental health

David Robson is an award-winning science writer and author of *The Laws of Connection: 13 social strategies that will transform your life*

"I often feel like I'm invisible," a Dear David reader complains. "My colleagues don't listen to my ideas and my friends take me for granted, but I'm afraid that if I express my frustration, it will only lead to conflict. What can I do to earn more respect?"

This letter got me thinking about the value of assertiveness, which is the capacity to express our feelings and needs directly, while maintaining respect for others. The latter part is crucial, as assertiveness cannot be an excuse for aggression. The problem is that many people, like our reader, veer too far in the opposite direction: they are so worried about seeming rude that they fail to say what they mean. One common sign is that you find yourself apologising for simply stating your opinion.

Assertiveness is considered an important leadership skill, but psychological research suggests it is also a keystone of general mental health. That makes sense: frank conversations can remove serious stresses from our lives, lift us out of a hopeless state and enhance our social relationships. For this reason, assertiveness training was once a popular treatment for many mental health conditions, but interest waned in the 1980s, 1990s and 2000s as other forms of talking therapy became more fashionable.

A paper in 2018 attempted to reverse this, and assertiveness training is again the subject of serious research. Such studies have confirmed that increased assertiveness can ease anxiety and depression and improve overall well-being. It is also essential for dating and, in schools, assertiveness programmes may prevent bullying.

JOHNNYGREIG/GETTY IMAGES

Assertiveness training typically involves a series of modules that aim to identify the unhelpful thoughts and beliefs that can prevent us from speaking frankly, such as "If I assert myself, I will upset the other person and ruin our relationship" or "It will all work out in the end and, anyway, it's not my fault" – a common excuse for not taking action.

Participants may be asked to keep diaries tracking their behaviour to help them come up with new ways of handling difficult interactions. The training may also include sessions on how to phrase assertive statements, including a recognition of the other person's feelings alongside their own, such as "I know you're busy at the moment, but I'd like to make a request of you". Further modules may examine techniques for coping with disappointment or criticism, or for accepting compliments without downplaying achievements.

Assertiveness training can be provided in person, as part of cognitive behavioural therapy, but the latest research suggests online workbooks may provide many of the same benefits. The time that you invest in developing such an essential life skill may pay dividends for years to come. ▮

Further reading

Australia's Centre for Clinical Investigations offers an online workbook called *Assert Yourself!* that is based on the principles of cognitive behavioural therapy: cci.health.wa.gov.au/Resources/Looking-After-Yourself/Assertiveness

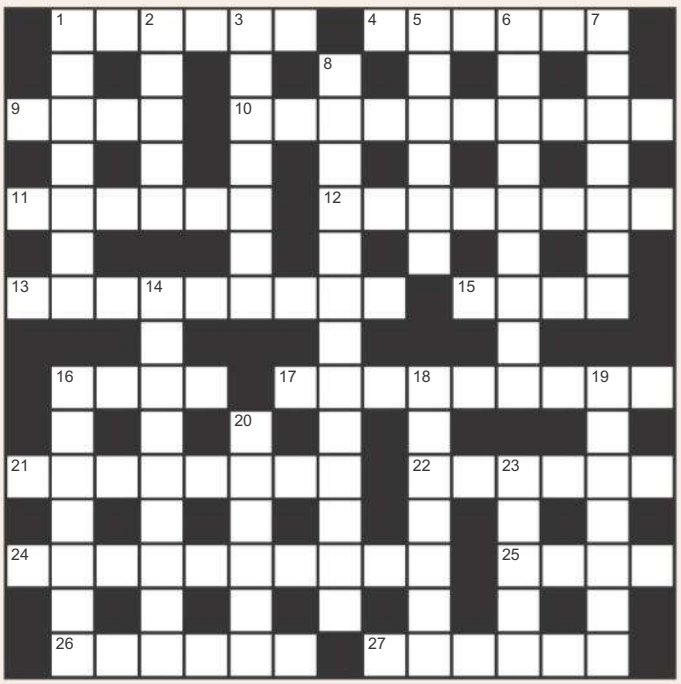
Dear David, an evidence-based advice column, appears monthly. Drop David a line with your social dilemmas at davidrobson.me/contact

These articles are posted each week at newscientist.com/maker

Next week

Stargazing at home

Quick crossword #195 *Set by Richard Smyth*



Scribble zone

Answers and the next cryptic crossword next week

ACROSS

1 Royalty-free virtual reality standard (6)
4 Spherical bacterium (6)
9 Robert ___, bacteriology pioneer (4)
10 Circular traffic intersection (10)
11 *The* ___, 1999 sci-fi action film (6)
12 Mathematical capacity (8)
13 Pd (9)
15 Stars (4)
16 Hollow in which water can pool (4)
17 Removed from a professional register (of doctors, perhaps) (6,3)
21 Aviation territory (8)
22 Distort (6)
24 Capacity of people to make mistakes (5,5)
25 Pb (4)
26 5th prime (6)
27 ___ boom, late-1990s tech bubble (3,3)

DOWN

1 Dragonfly order (7)
2 $(CH_3CH_2)_2O$, say (5)
3 Photocopied (7)
5 Fluid retention (6)
6 Sci-fi aesthetic associated with William Gibson (9)
7 Origins (7)
8 Branch of particle physics (7,6)
14 Deposit of (mainly) $CaCO_3$ (9)
16 Fit (7)
18 Experience, be subjected to (7)
19 Part of the upper limb (7)
20 Sex cell (6)
23 Relating to vitamin B9 (5)

Our crosswords are now solvable online
newscientist.com/crosswords

Quick quiz #326
set by Tom Leslie

1 Europe's longest dinosaur trackway made by a single sauropod was uncovered in which English county earlier this year?

2 Last month, SpaceX's Starship executed a successful test flight that saw it travel from south Texas to where?

3 Researchers at the University of Surrey, UK, recently discovered what unusual physiological response to stress?

4 Green turtles were in the news in October because their populations are rebounding. But what makes them green?

5 What was used in the Artemis I mission in 2022 as an indicator of zero gravity?

Answers on page 47

BrainTwister
set by Sophie Maclean

#97 Picking and choosing

Choose a set of numbers from 1 to 100.

What is the size of the largest set you can choose such that no two numbers are consecutive?

What is the size of the largest set you can choose such that no three numbers are consecutive?

What is the size of the largest set you can choose such that no two of the numbers differ by 2?

What is the size of the largest set you can choose such that it contains no sequence of three numbers that increment by 2? (e.g. 1, 3, 5 can't all be in the set, but any two of them can.)

Answers next week

I know you

Which animals can recognise individual people? Are there fish, reptiles or insects that can do this?

Sara I. Paisa
Bucharest, Romania
I am a keen birdwatcher and in the past year or so, I have observed that magpies and doves can recognise individual people. I have also read that other corvids have this ability too.

They go through a process of active learning. Initially, they tend to be afraid of humans. As time goes by, caution turns into curiosity, then into interest. We know that magpies are fond of shiny objects, so me seeing them near my window isn't a surprise, especially during sunny days. The doves, I suspect, have a nest near my home, like the family of magpies, and go through the same process of recognising individuals. Both species are clearly capable of distinguishing me and my family from other people in this area.

On a trip to the Tower of London, I greeted one of its ravens with a simple "Hello!". It tilted its head in the same way that dogs do when paying close attention to something, indicating that the raven was actively engaging with me.

"Given the variety of sensory worlds they inhabit, animals may even use senses we would never expect to tell people apart"

Francesca Cornero, Willa Lane and Nicky Clayton
University of Cambridge, UK
Studies and anecdotal evidence both suggest that most mammals – including great apes, dolphins, elephants, polar bears, dogs, cats, horses, sheep and pigs, among others – recognise individual people. Birds do as well, signs of which are found in a variety of species, although some of the most convincing scientific evidence has been from the parrot and corvid families. For example, in laboratory studies, crows have learned to identify the faces of threatening humans and they continue to mob them over years – even crows that hadn't experienced the harassment learned to target the same humans.

Individual recognition isn't limited to the mammalian or avian worlds, however. Octopuses sometimes spit water at people they dislike. Their cuttlefish cousins are also probably capable of recognising individual humans: one of us noted that a cuttlefish in a laboratory stopped reacting to a specific researcher who always moved quickly, but would ink or jet away if other people moved at the same fast pace. There is also evidence that fish such as archerfish and sea bream, reptiles like tokay geckos and corn snakes, and insects including honeybees and wasps can learn to recognise individual humans. This is probably a natural extension of their existing ability to discriminate between safe and unsafe features of the physical and social dynamics of their environment – for example, to categorise friends and foes.

As research continues, we will probably find even more species that are capable of recognising individual humans. Given the variety of sensory worlds they inhabit, they may even use senses we would never expect (or haven't yet discovered!) to tell people apart.

SHUTTERSTOCK/HOLLY MICHELE

What happens when a spinning disc approaches the speed of light?

This week's new questions

Spinning around **If a very large disc on a frictionless, horizontal spindle were gradually rotated faster and faster, what would happen as the rim approached the speed of light?** ***Neil Buchan****, Reading, Berkshire, UK*

Listen up **What part, if any, do my ears or auditory system play when I generate a tune in my head?** ***John Howes****, Cardiff, UK*

Tip of my tongue

How can my brain predict if I'll recall a name or word in a minute or two, or if I won't remember it at all?

Daniel Bellhouse
Leeds, UK
The "tip of the tongue" feeling suggests that some parts of the memory network are activated, but not enough to fully recall the information, akin to having a faint signal but not the full transmission. Another analogy would be arriving at a filing cabinet with an index card pointing to a blank location. The presence of the index card suggests the information exists, but has been temporarily misplaced or misfiled. The brain interprets this as a transient situation, with the expectation that the information will be found with a little rummaging in nearby files.

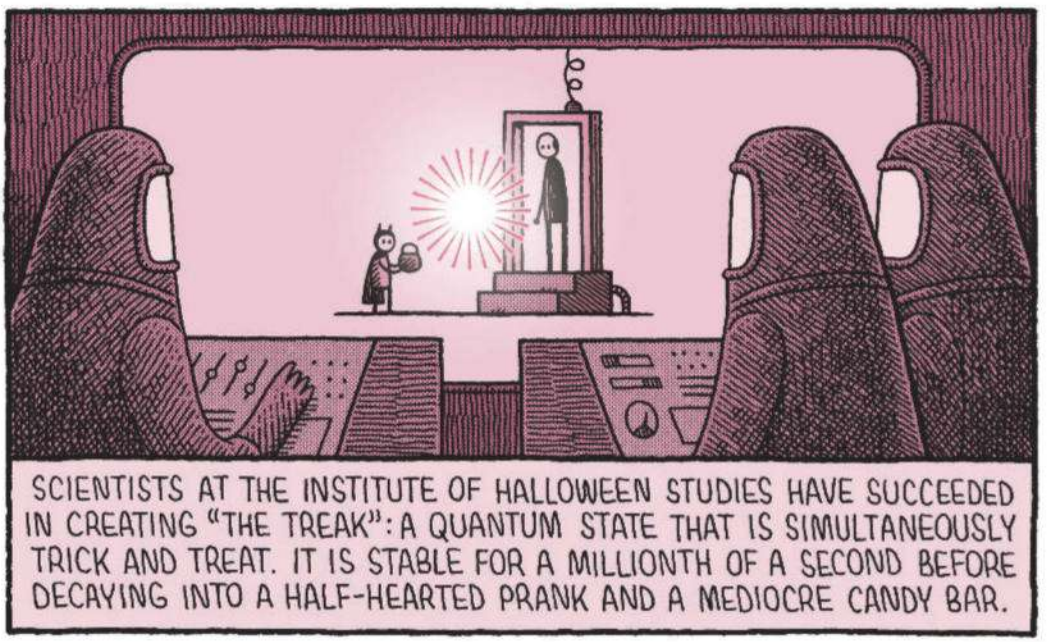
Jon Hinwood
Melbourne, Australia
Until recently, I could tell with 90 per cent accuracy when I would remember a fact or name, ranging from "just hang on a minute" to "I'll tell you in 20 minutes" to the deeply buried "that'll come at dinnertime tomorrow".

The long delays for some words suggest that the brain has to search through very large numbers of ever-weaker synaptic links with slow transmission rates before locating the target one. I think this is part of a complex cross-referenced mental catalogue that would also help recover a name if given the initial letter.

I still retain another catalogue stream: I can often recall the shape of a word that I am struggling to remember, how many syllables it has, which ones are stressed or elided, and whether there are any sibilants. Smell is also a powerful catalogue stream and sound is too, but both of these, I think, require practice to develop.

Want to send us a question or answer?
Email us at lastword@newscientist.com
Questions should be about everyday science phenomena
Full terms and conditions at newscientist.com/lw-terms

Tom Gauld
for New Scientist


SCIENTISTS AT THE INSTITUTE OF HALLOWEEN STUDIES HAVE SUCCEEDED IN CREATING "THE TREAK": A QUANTUM STATE THAT IS SIMULTANEOUSLY TRICK AND TREAT. IT IS STABLE FOR A MILLIONTH OF A SECOND BEFORE DECAYING INTO A HALF-HEARTED PRANK AND A MEDIOCRE CANDY BAR.

Twinkle twinkle

If you could approach closely enough (which, of course, you couldn't), what would the surface of a neutron star look like? (continued)

Ron Dippold
San Diego, California, US
If you approached a neutron star, you would be instantly crushed by gravity and fried by X-rays, while your very atoms would be torn apart by magnetic fields and gravity – making you a splattered stain on the surface.

But let's wave our magic wand and let you survive. This surface is a thin, neutron-rich lattice "crust" a couple of hundred metres thick over neutron fluid sloshing around inside. There would be intense gravitational lensing. A neutron star is halfway to becoming a black hole, so light would be visibly bent. Unlike Earth, where you can see things drop below the horizon (proving it is a sphere), you could see up to about 80 per cent of a neutron star while standing still, since the light is bent so much!

"The long delays in retreiving words suggest the brain has to search through large numbers of ever-weaker synaptic links"

Time runs about 20 to 30 per cent slower here due to the extreme gravity, so things seem to orbit faster and are blueshifted. The airless sky would be full of auroras from the intense magnetic fields, especially if the neutron star were a pulsar. If you dropped anything, it would reach the surface in less than a microsecond and cause a nuclear explosion with intense gamma and X-rays.

If it were orbiting a star like our sun, the light from the neutron star would be bluer and brighter due to gravitational lensing and time dilation. If it were new, it could be 1 million °C and there might be some blue glow from this heat, but you would probably only be able to see that in X-ray wavelengths.

Once it cooled down, the neutron star would be dark and only lit by its companion star. You might still see some bright spikes at the poles from the magnetic fields. From Earth, the neutron star would be invisible to our eyes, given it would be only about 12 kilometres across, even though it would be 40 per cent more massive than our sun.

If I had a magic wand of invulnerability, I would definitely want to visit a neutron star. But once would probably be enough.

Eric Kvaalen
Les Essarts-le-Roi, France
You wouldn't be able to look at a nearby neutron star with the naked eye, as it would be glowing with a bluish light so strong it would blind you.

But if you had enough pairs of sunglasses on, you would see just blue light. You wouldn't, however, be able to discern that the surface is very smooth and composed not of neutrons, but of atoms of carbon and oxygen. There would be a very thin plasma of carbon and oxygen above the surface, but you wouldn't see that either.

Answers

Quick quiz #326 *Answer*

1 Oxfordshire
2 The Indian Ocean
3 Your nose gets colder
4 Seagrass and algae in their diet
5 A plush Snoopy doll

Cryptic crossword #173 *Answers*

ACROSS 1 Chrome,
5 Bolts, **9** Oared, **10** Calibre,
11 Beet red, **12** Delft, **14** Behave,
16 Uganda, **18** Dream,
19 Proverb, **22** Webbing,
24 First, **25** Drupe, **26** Tirade

DOWN 2 Horseshoe,
3 Order, **4** Encode, **5** Bulldog,
6 Lab, **7** Spectra, **8** Tomb,
13 Long-eared, **14** Bedewed,
15 Vampire, **17** Spigot,
20 Offer, **21** Bats, **23** BTU

#96 Multiplying dice *Solution*

The average value of each die is 3.5, so because the dice are independent, the average value of the product is $3.5^2 = 12.25$.

Pairs of values whose product is greater than 12.25 are (3,5), (3,6), (4,4), (4,5), (4,6), (5,3), (5,4), (5,5), (5,6), (6,3), (6,4), (6,5), (6,6). That is 13 of 36 possible pairs, or a probability of $13/36 \approx 36.1$ per cent. The product is, more often than not, less than the average product.

The average value of the product of three dice is $3.5^3 = 42.875$. There are 78 triples whose product is greater than that, a probability of $78/216 = 13/36 \approx 36.1$ per cent.

Digging in

There are few things Feedback appreciates more than a truly committed hobbyist: someone who happily spends months or even years building something that is of no practical use whatsoever, just to be able to look at it or play with it.

So, then, to the online world of *Minecraft*. For those who might be unfamiliar, *Minecraft* is an open-world game in which everything is made up of cubical blocks. Players dig into the ground to collect cubes of useful minerals, which they can use to build things. For instance, they might build a house so that the monsters that come out at night can't get them.

Or they might go big. Really big. Feedback is fond of a group called Minecraft Middle Earth (shouldn't that be Minecraft Middle-earth?) whose members have constructed some of the biggest locations from J. R. R. Tolkien's stories, like Minas Tirith and the mines of Moria (of course). The group says its map of Middle-earth has an area of 29,000 by 30,000 blocks.

In terms of sheer scale, a *Minecraft* project of an entirely different sort by YouTuber sammyuri is puny by comparison, with a volume of a mere 1020 x 260 x 1656 blocks. But it is impressive in another way: it's a large language model (LLM), like ChatGPT or Claude. Sammyuri has inevitably called it CraftGPT.

The YouTuber built CraftGPT using redstone, which in the game is a mineral that behaves like electrical circuitry and can be used to build mechanisms. Most players use redstone to make simple things like traps for monsters, but sammyuri has taken it and run with it. In fact, in a meta twist, they previously built a crude version of *Minecraft* within *Minecraft*.

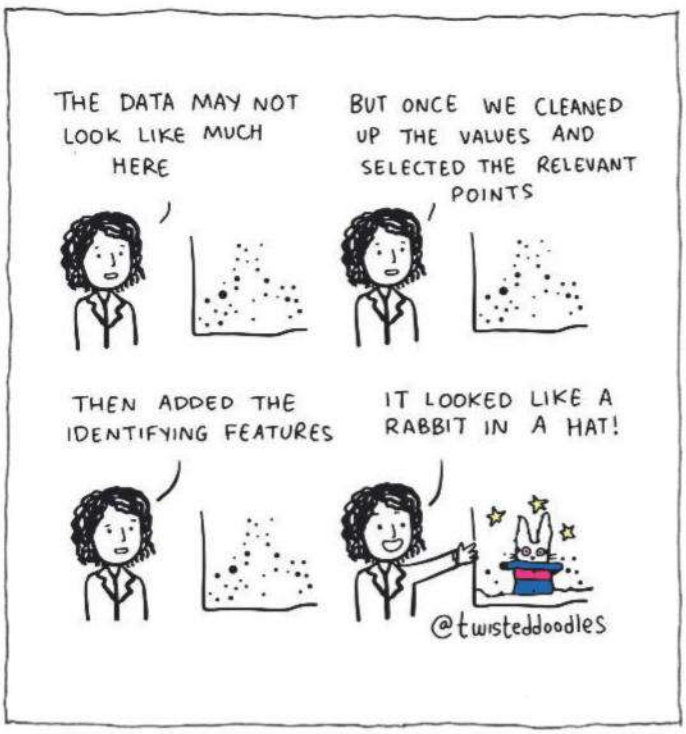
Their new construction starts with a keyboard and screen, allowing players to enter prompts and see the model's responses. Behind that is a towering array of redstone blocks, like a city with hundreds of skyscrapers. They are configured to mimic the components of an LLM, like a tokeniser, a KV cache and a rectified linear unit (ReLU).

All of this enables CraftGPT to conduct conversations like: "Hello, how are you today?" "I am feeling quite happy today, thank you for asking." It can correctly tell you that the sky is blue and that fruits are healthy to eat. When sammyuri asked, "Did you know you are a machine?" CraftGPT responded "Yes, I think it is quite interesting, especially with new technology and technology". This led sammyuri to wrily conclude that CraftGPT "probably" doesn't know it's AI.

On the one hand, nobody could accuse sammyuri of false modesty about this. Their video on CraftGPT begins with a text warning that "some viewers... may suffer adverse effects including but not limited to having their minds blown in spectacular fashion". However, they do go on to say that CraftGPT is "technically a 'small language model' given it's only got 5 million parameters; that was about as much as my poor old laptop could handle."

Feedback found ourselves staring glassy-eyed at the huge arrays of redstone, which are necessarily repetitive. Hugely, stunningly repetitive. We can't imagine how boring it was to build them.

Twisteddoodles *for New Scientist*


THE DATA MAY NOT LOOK LIKE MUCH HERE
BUT ONCE WE CLEANED UP THE VALUES AND SELECTED THE RELEVANT POINTS
THEN ADDED THE IDENTIFYING FEATURES
IT LOOKED LIKE A RABBIT IN A HAT!
@twisteddoodles

Got a story for Feedback?
Send it to feedback@newscientist.com
or New Scientist, 9 Derry Street, London, W8 5HY
Consideration of items sent in the post will be delayed

It's a me!

While we're on the subject of video games, Feedback recently became aware of a major shakeup in the gaming world. The president of Nintendo America is stepping down at the end of the year after almost a decade in his post. That's 10 years of supervising new Mario games, in which the jumpy Italian plumber faces off against Bowser the giant evil tortoise and his armies of Koopa Troopas and Goombas, all to safeguard Princess Peach and her bafflingly undefended Mushroom Kingdom.

But perhaps it was always meant to be, given the soon-to-be-ex-president is called Doug Bowser.

Reinventing the paper

At this point, Feedback is pretty wise to the technology hype machine. There's only so many times you can read claims that some "game-changing" start-up company is "disrupting" a sector of the economy by "revolutionising" how some task or other is performed, before you become suspicious.

So, to a truly disruptive new technology, a "minimalist, paper-based to-do manager" reviewed highly positively by both *The New York Times* and *Wired* in the last year. Known as Analog and produced by a company called Ugmonk, it is intended to replace online task-management tools, so that you can work offline without the distractions of social media. It is a wooden block that sits on your desk, with a bunch of lined white cards with bullet points for you to fill in your tasks.

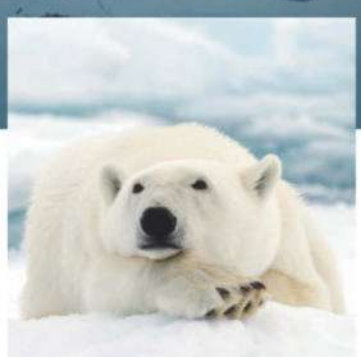
In other words, it's some index cards and a piece of wood. The *NYT*'s reviewer called it "delightfully old-school". She did anticipate the obvious question: "Why not just use a notebook, right?" However, such approaches "have never worked" for her, whereas "the Analog system speaks to my Gemini spirit, allowing me to feel both professionally serious and surprisingly free."

An Analog starter kit will set you back £75. Then you need to keep buying the cards. An annual refill will normally cost £141, but there is an alternative: Ugmonk helpfully allows you to take out a monthly subscription to get a regular supply. Yes, it's yet another example of a company trying to sucker you into paying them money every month for a service you probably won't use but will forget to cancel.

Feedback is, by the way, aware of the irony of pointing this out while also being part of a magazine that sells subscriptions. You don't need to write in to tell us.

New Scientist Discovery Tours

Experience an unforgettable polar cruise with experts



Arctic expedition cruise with Dr Russell Arnott: Svalbard, Norway

17 June 2026 | 12 days

This is no ordinary cruise exploring Svalbard's wild beauty – it is a carefully designed scientific expedition that blends discovery with adventure. Delve into the region's unique ecosystems, witnessing glaciers, wildlife and Arctic waters up close, all guided by marine biologist and oceanographer Dr Russell Arnott, who brings the science of the ocean to life.

Highlights include:

- Sail aboard the state-of-the-art Greg Mortimer, combining luxury with access to remote environments
- Get closer to the region's thriving wildlife, from polar bears to seabird colonies

Spirit of Antarctica expedition cruise: Antarctic Peninsula

7 December 2026 | 12 days

Join an extraordinary voyage, where science, adventure and discovery converge in one of the most remote and awe-inspiring places on the planet. Accompanied by *New Scientist*'s Rowan Hooper and marine biologist Dr Russell Arnott, discover the White Continent through a journey that blends breathtaking natural encounters with unique scientific knowledge.

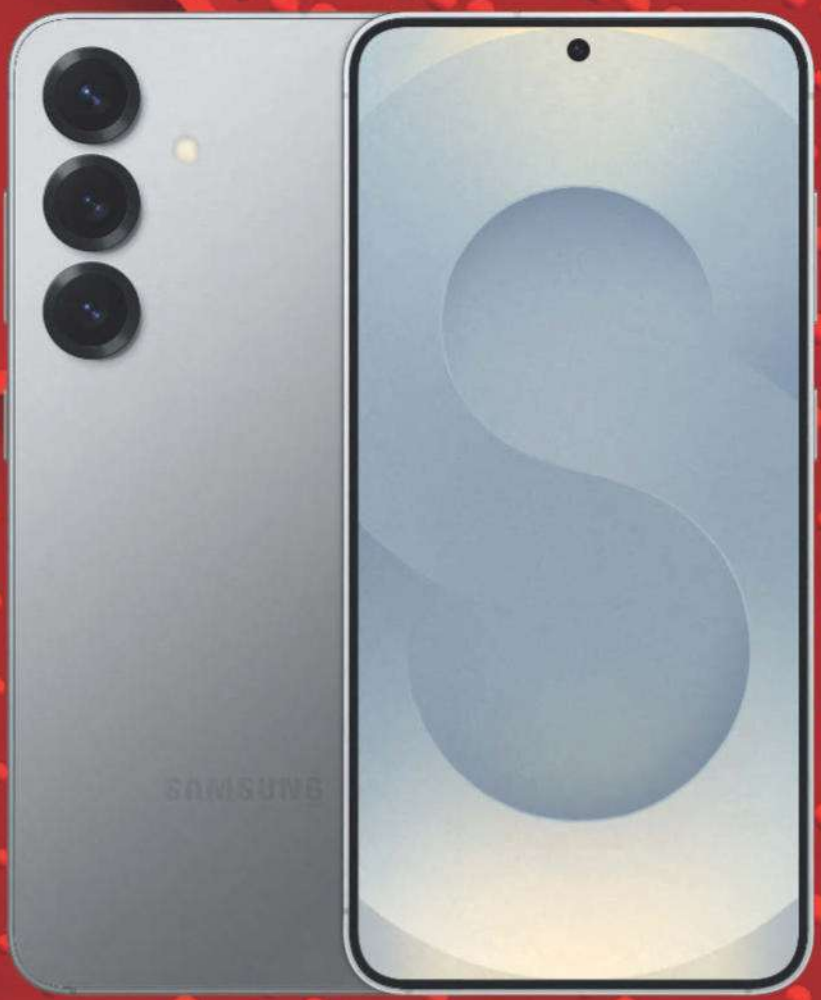
Highlights include:

- Explore the frozen frontier with daily Zodiac cruises and guided hikes
- Unforgettable encounters with vast penguin colonies, majestic whales and towering icebergs

Where will your curiosity take you?
newscientist.com/tours

vodafone business

SAMSUNG



Get the Galaxy S25

A True AI Companion

Scan to shop